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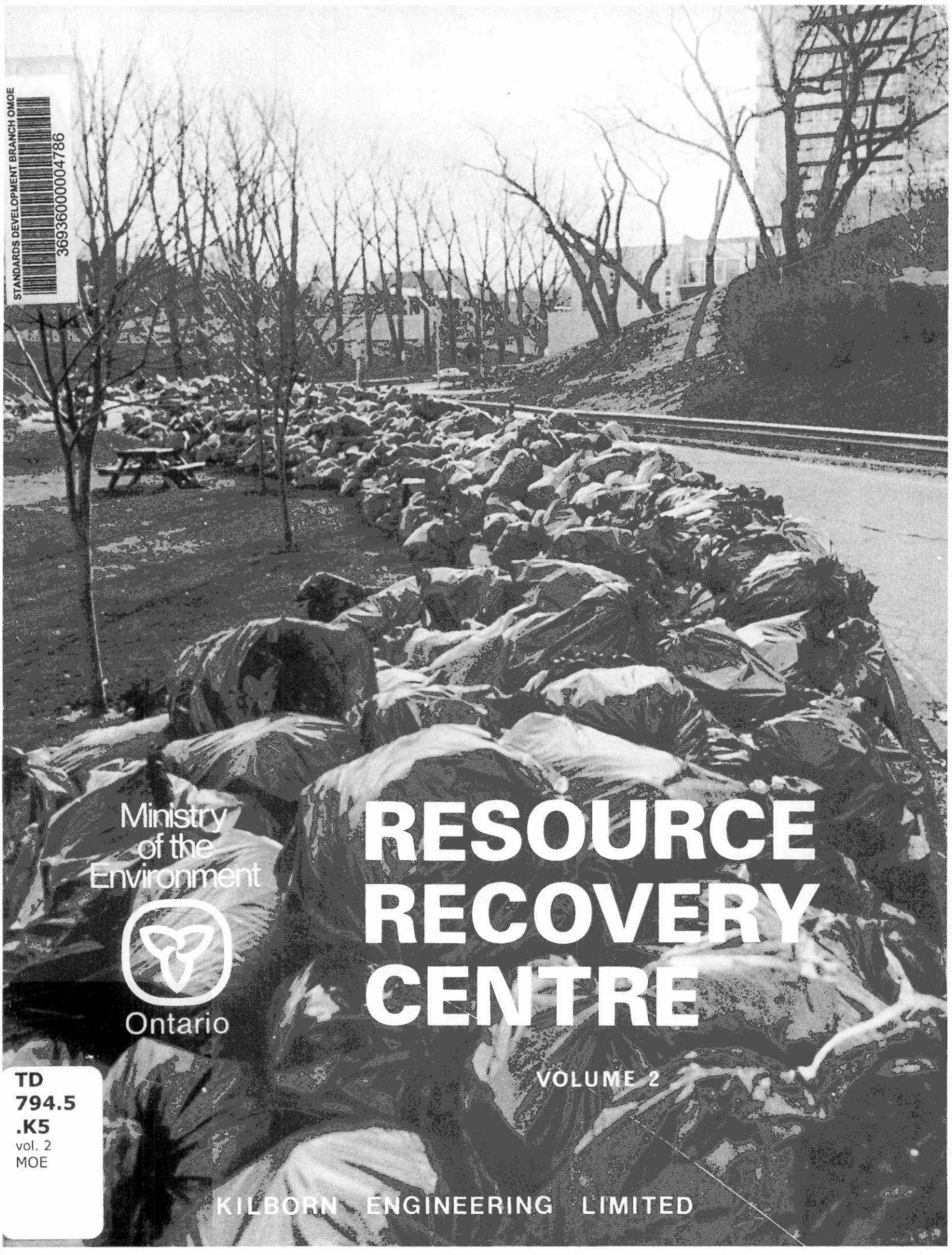

Ministry of the Environment

Ontario

RESOURCE RECOVERY CENTRE

VOLUME 2

KILBORN ENGINEERING LIMITED

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C O N T E N T S

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S E C T I O N 1 3

INTRODUCTION TO VOLUME II

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INTRODUCTION

Volume II, comprised of general information on the make-up of solid waste, markets, and present technology applicable to the solid waste industry, forms the background used to provide guidelines for the design flexibility incorporated in the layout of the proposed experimental waste reclamation plant shown in Volume I.

Volume II also provides the economic base for the positive recommendations regarding the long-term benefits of reclamation as an alternate to present disposal methods.

It illustrates in tables the relative potential of reclamation versus energy conversion or incineration, and also indicates the magnitude of the effort required to realize this potential.

It has been the goal to try to present the known and developing technology on equal terms regarding real and anticipated performance and, where possible, confirmed by site visits. Since the technology has been obtained from Europe as well as North America, it is imperative to take into consideration differences in wage levels, fuel costs, social customs and climate before attempting to relate the values to North American situations.

S E C T I O N 1 4

MUNICIPAL SOLID WASTE

MUNICIPAL SOLID WASTE

14.1 THE MAKEUP OF SOLID WASTE

The makeup of solid waste changes from day to day, season to season, area to area within a city. It also varies in different parts of the country and varies from country to country changing from year to year.

While it is a relatively easy matter to identify the makeup of a specific sample, it is difficult to obtain an average sample from which to predict year round quantities.

Table 14.1.1 shows a number of analysis that have been reported. Table 14.1.2 shows three analysis performed on Toronto solid waste as collected by the City. These later figures show a high domestic waste level as evidenced by the percentage of food and vegetation. Since any waste reclamation plant will be required to handle either domestic or commercial refuse, or a combination of both, we are for the purpose of comparison using average figures as shown in the table following, (table 14.1).

TABLE 14.1

Average Figures for Municipal Solid Waste as used in this report (per cent of total) Bone Dry Basis.	
Paper and Cardboard	50
Food Waste and Vegetation	22
Plastic, Rubber and Leather	3.6
Rags	2.6
Wood	3.2
Glass and Ceramics	8.4
Metals	8.0
Inerts	2.2

The figures shown also indicate the quantitative variations that a plant must have the capability to handle.

TABLE 14.1.1

SOME ANALYSES OF SOLID WASTE (BONE DRY BASIS)

(per cent of total)

LOCATION	(1) San Diego %	(2) California %	(3) Gainsville %	(4) Montreal %	(5) Quebec City %
Combustibles					
Paper and Cardboard	50.7	51.5	53.4	50.0	67.3
Food Waste) Vegetation)	4.4	15.5	21.8	22.0	9.9
Plastics, Rubber, Leather	5.5	3.0	2.8	3.6	1.9
Rags	3.8	4.0	2.1	2.6	.3
Wood	4.0	2.0	.2	3.2	4.8
Miscellaneous (Combust)	3.5	4.0	-	-	-
	71.9	80.0	80.3	81.4	84.2
Non-Combustibles					
Glass and Ceramics	10.0	8.0	6.5	8.4	7.2
Ferrous Metals	8.0	6.0	7.6	8.0	8.6
Non-Ferrous Metals	1.1	1.0	(Incl. Above)	Incl.	Incl.
Inerts	19.5	5.0	5.6	2.2	-
	38.6	20.0	19.7	18.6	15.8
	100.0	100.0	100.0	100.0	100.0

1) Hoffman, D. A. - Environmental Science and Tech. - November, 1968 - P. 1023.

2) S.E.R.L. Report 691. 1969.

3) Westerhoff, G.P Public Works, November, 1969.

4) S.N.C. Report - 1972.

TABLE 14.1.2

ANALYSIS OF SOLID WASTE (DOMESTIC) FOR TORONTO

(per cent of total)

BONE DRY BASIS

	(1) September, 1966. %	(2) June, July, 1973. %	(3) August, 1973. %
Combustibles			
Paper and Cardboard	39.5	43.8	28.7
Food Waste	32.4	12.3	12.9
Vegetation	6.5	12.5	34.6
Plastics, Rubber, Leather	2.6	3.6	3.6
Rags and Textiles	1.5	6.2	1.6
Wood	1.1	4.6	2.0
Miscellaneous (Combust)	1.1	3.4	-
	84.7	86.4	83.4
Non-Combustibles			
Glass and Ceramics	8.0	5.2	8.7
Ferrous Metals	5.8	6.0	4.4
Non-Ferrous Metals	.1	1.1	1.0
Inerts	1.4	1.3	2.5
	15.3	13.6	16.6
	100.0	100.0	100.0

1) McLaren Report, 1967.

2) Ministry of the Environment.

3) Samples taken by Horner and Shrifrin Inc.

14.2 POTENTIAL USES OF COMPONENTS OF SOLID WASTE

Since modern solid waste as received has an average net heat content of approximately 5,000 BTU per lb., the most obvious use of solid waste is as fuel, particularly in the larger communities.

However, fuel or energy is one of the least expensive modern commodities as evidenced by its market price.

Comparative prices of energy on a BTU basis are as follows:

Electricity (@ 1¢/KW Hr)	- $2.85 per million BTU
Natural Gas (@ $1.00/1000 C.F.)	- $1.00 per million BTU
Domestic Oil (@ 22¢/Imp gal) (wholesale price)	- $1.53 per million BTU
Bunker C fuel (@ 16¢/Imp gal)	- $1.05 per million BTU
Soft Coal (@ $15.00/ton	- $ .65 per million BTU
Low Sulphur Coal (@ $19.00/ton)	- $ .76 per million BTU

Since waste used as fuel generates ash and particulate matter, its maximum value on today's market must be compared to low sulphur coal.

On this basis, as a fuel, one ton of waste has a value of about $7.60, assuming that burning efficiencies are equal.

14.2 (Cont'd)

An examination of the original bulk value of the components of solid waste is revealed in Table 14.2. Applying these values and the percentage of each found in solid waste (Table 14.1) gives an indication which fractions offer the greatest possibilities for reclamation, and where the emphasis on reclamation efforts should be placed, (Table 14.2.1).

TABLE 14.2

ORIGINAL VALUES OF COMPONENTS IN SOLID WASTE

Component	Original Per Ton Range of Value *	Original per Ton Average Value
- Paper Products		
Newsprint, corrugated cardboard, fine paper, cartons	$180/ton to $235	$200.00
- Ferrous Metals		
Tin Cans, bottle caps, nails, tubing, pipe, sheet metal	$180/ton to $600	$400.00
- Non-Ferrous Metals		
Copper, zinc, lead aluminum	$340/ton to $1200	$700.00
- Glass	$ 27/ton	$ 27.00
- Plastics		
Polyolifins, styrene, P.V.C., ABS	$600/ton to $800	$700.00
- Rubber, leather	$700/ton to $800	$750.00
- Textiles - Nylon, Dacron, wool, cotton, polypropylene	$480/ton to $1600	$500.00
- Wood	$ 30/ton to $400	$ 40.00
- Inerts	-0-	-0-
- Garden and Plant Waste	-0-	-0-

* Values as of December, 1973.

TABLE 14.2.1

ESTIMATED VALUES IN SOLID WASTE - PRESENT AND POTENTIAL

Commodity	Original Market Value ($ per ton) 1	Commodity available per ton solid waste (%) 2	Maximum potential value per ton solid waste if recycled ($ per ton) 3	Present known use as salvage material 4	Present market value per ton as salvage material ($ per ton) 5	Present value per ton of solid waste as salvaged material ($ per ton) 6	Unrecovered value per ton of solid waste as salvaged material ($ per ton) 7	Potential uses for recycled material 8	Potential value per ton as recycled material ($ per ton) 9	Estimated per cent recovery in solid waste (%) 10	Actual potential value per ton solid waste if recycled ($ per ton) 11	Possible increase in value if recycled over value as presently used ($ per ton) 12
Paper and Miscellaneous	$200.00	50.0 %	$100.00	Fuel	$12.18	$6.09	$93.91	Newsprint	$200.00	75%	$ 75.00	$68.91
Ferrous Metals	400.00	6.5 %	26.00	Rawscrap	15.00	.98	25.02	#2 Scrap	60.00	90%	3.52	2.54
Non-Ferrous Metals	700.00	1.5 %	10.50	Scrap	20.00	.30	10.20	Bar Metal	500.00	90%	6.75	6.45
Glass	27.00	8.4 %	2.27	Road Surfacing	1.00	.08	2.19	Cullet	15.00	80%	1.02	.94
Plastics	700.00	3.0 %	21.00	Fuel	13.00	.39	20.61	Plastic	600.00	60%	10.80	10.41
Rubber and Leather	750.00	.6 %	4.50	Fuel	12.00	.07	4.43	Reclaimed Rubber	400.00	50%	1.20	1.13
Textiles	500.00	2.6 %	13.00	Fuel	8.00	.21	12.79	Rags	400.00	25%	2.60	2.39
Wood	40.00	3.2 %	1.28	Fuel	8.00	.26	1.02	Paper	200.00	40%	2.56	2.30
Inerts	-0-	2.2 %	-0-	None	-0-	-0-	-0-					
Garden and Plant Waste	-0-	22.0 %	-0-	Compost	-0-	-0-	-0-	Fertilizer	40.00	25%	2.20	2.20
		100.0 %	$178.55			$8.38	$170.17				$105.65	$97.27

Col. 3 = Col. 1 x Col. 2	Col. 6 $\pm$ Col. 5 x Col. 2	Col. 7 = Col. 3 - Col. 6
Col.11 = Col. 9 x Col. 2 x Col. 10	Col. 12 = Col. 11 - Col. 6	

14.3 VALUES IN SOLID WASTE

Since the dollar value of a product is a fair measure of the amount of human effort that has gone into its production, the analysis (estimated values) of the potential value per ton of waste, should be a good indication of where research effort could return the greatest results.

When used as a fuel, theoretical maximum recoverable value per ton of waste is about $8.14 ($6.78 combustibles + $1.36 non-combustibles).

Assuming a possibility of 100% conversion to other forms of fuel, the following values per ton of waste appear.

Methane (natural gas)	- 10.00/Ton + 1.36 = $11.36
Domestic Oil (@ 15,000 BTU/lb)	- 12.75/Ton + 1.36 = $14.11

Normally, natural gas is considered a premium fuel relative to the fuel oils, and commands a slightly higher price in the energy market. Comparative prices per million BTU emphasize the distortions that can occur because of delays in price adjustments, long term contracts, etc.

Generally, the indication, therefore, is that in whatever fuel form solid waste is utilized, very little additional benefit can be obtained.

14.3 (Cont'd)

Table 14.2.1 emphasizes the large improvement in value that may be obtained from other potential uses, rather than as a fuel.

Theoretical maximum, relative potential improvement in values that may be possible is shown in descending order of value. (Scale of worth)

TABLE 14.3

POTENTIAL IMPROVEMENT IN VALUES POSSIBLE IF RECLAIMED AND RECYCLED

(Theoretical Maximum)

Recycled Commodity	$ per ton of Solid Waste
Paper and miscellaneous paper products	$68.91
Plastics	10.41
Non-Ferrous Metals	6.45
Ferrous Metals	2.54
Textiles	2.39
Wood	2.30
Fertilizer	2.20
Rubber and Leather	1.13
Glass	.94

This is an indication then of where emphasis for recovery from an Experimental Reclamation Plant may best be applied for maximum value return.

S E C T I O N 1 5

MARKETING

MARKETING

Forward and Definitions

Since this is to be a Canadian Facility operated in Canada with the products marketed mostly in Canada, the market assessment refers to Canadian Markets.

Existing Markets refers to markets presently being served by products recovered from solid waste.

Potential Markets are existing markets for which it appears that a product recovered from solid waste could qualify, but which are presently being supplied by a product from other sources.

15.1 PLANT MARKETING OBJECTIVES

The success of any manufacturing industry depends wholly on the marketability of the products produced.

In this way, a Resource Recovery plant using solid waste as input is no different from any other recovery industry.

Consequently, a main objective of an Experimental Waste Recovery or Reclamation plant is to provide a facility where technology can be evaluated, modified and perfected to enable marketable products to be produced in sufficient quantity, quality, and reliability, to enable letters of intent and eventual contracts to be obtained from customers.

15.1 (Cont'd)

In most recovery operations, plant management can exercise a degree of control over the quality of raw material brought into the plant, and certainly exercises control over the quantity. A solid waste Resource Recovery Plant differs in this regard, as controlling or limiting any detrimental input material would be a long term effort requiring possible legislation. The generation of raw material is a daily occurrence that must be accepted as it is found.

15.2 MARKETABLE COMPONENTS

Marketable components of solid waste are shown in Table 15.2 outlining uses, presently used methods of recovery, today's market value, and the amount of the various components available for reclamation.

It is obvious from an examination of the present market evaluation of the products of solid waste, that these markets must also be near the point of generation, as transportation costs per ton mile could soon make the whole concept uneconomical.

Taking each of the marketable products into consideration the following becomes apparent.

TABLE 15.2

PRESENT MARKETABLE COMPONENTS OF SOLID WASTE

VALUES - MARKETS

Material	Established Markets	Acceptable Form for Market	Present Recovery Methods	Value/Ton	Possible Contribution to Recovery of Value ($ per Ton)	Available for Reclamation from Solid Waste (1) (% per Ton)
Select corrugated board	(1) Raw pulp for liner board and corrugating mill	Baled, clean, dry	Manual	$40 - $80	$2.40 to $4.80	6%
	(2) Raw pulp for boxboard, cardboard boxes	Baled, clean, dry	Manual	40 - 80		
Newsprint	(1) Newsprint	Clean, baled, dry	Manual	10 - 20	.50 to 1.00	5%
	(2) Boxboard, cardboard	Clean, baled, dry	Manual	10 - 20		
Clean White Paper	Fine papers	Clean, baled, dry	Manual	40 - 80	.40 to .80	1%
Glass	Cullet for glass plant	Clean, colour separated	Manual	10 - 15	.84 to 1.26	8.4%
Ferrous Metals	Copper leaching process	Clean cans whole or shredded	Magnetic	20 - 75	1.30 to 4.80	6.5%
	As scrap for Steel Plant	De-tinned - Clean	Process Plant	40 - 75	2.60 to 4.80	
Non-Ferrous Metals Aluminum	Re-melted for re-use	Clean	Manual	100 - 200	.30 to .60	.3%
Copper	Re-melted for re-use	Clean, pure	Manual	600 - 800	1.20 to 1.60	.2%
Rubber	Re-used in tires, mats, other rubber products, fuel	Clean tires only		-0-		.6%
		Any	Fired in boiler	-0-		

(1) Clark & Brown "Municipal Waste Disposal"

15.2.1 Paper Products as Marketable Component

In solid waste, normally about 12% is corrugated board, of which about 50% is recoverable, the balance is unsuitable or not easily removed.

Unless newsprint is recovered at the source, it is difficult with present technology to extract a large value from this component of mixed solid waste in the existing paper producer markets.

The problems associated with marketing quantities of clean white paper from mixed solid waste are even more formidable because of the higher quality control requirements of the process.

From the foregoing examination of the paper products fraction of solid waste, it appears that the dry separation method can provide a product that could assist in developing either the potential fuel market or with reprocessing, a pulp fibre market or a combination of both.

15.2.2 Ferrous Metals as Marketable Component

The steel scrap market fluctuates considerably but is quite large, certainly large enough to conceivably accept everything produced by reclamation plants. Metals must, however, be clean and must be processed to remove tin, plastic and lead. While the use of clean tin cans for the copper leaching process is a

good market for the reclaimed product, it is so small that it cannot be considered as an extensive outlet for this component. Consequently there exists only a small specialized portion of the scrap market available to ferrous material recovered from solid waste.

15.2.3 Glass as a Marketable Component

Present markets for glass cullet require separated clear or coloured container glass. Specifications for either type are difficult to meet, but the market exists and could accept large quantities of product generated that is competitive in quality and cost with new material. Glass is presently recovered in all the known processes in the form of mixed clear and coloured material. There is not a known market for the mixed product in this form.

15.2.4 Non-Ferrous Metals as Marketable Components

The present market for scrap aluminum, copper, zinc, tin, and the other non-ferrous metals is fair. At present the only separation method utilized commercially is hand separation. The material as received from a Primary separation plant is a mixed combination of elements and alloys and has no present known market.

15.2.5 Plastic Materials

No markets presently exist for plastics reclaimed from solid waste.

15.2.6 Organic Materials

A small market exists for organics as compost. May be used as prepared for a soil conditioner or mixed with other standard fertilizers.

15.2.7 Summary

An examination of the present marketable components, their economics, markets, and recovery techniques, reveals the following situation.

TABLE 15.2.7

PRESENT ECONOMICS (CANADA) FOR

MATERIALS COLLECTED FROM MUNICIPAL SOLID WASTE

Material	Value/Ton Solid Waste	Present Recovery Method	Probability of economics being favourable under present conditions.
Select Corrugated Board	$2.40 to $4.80	Manual	Very good - It appears that sufficient tonnage can be recovered to justify separation in a primary plant.
Newsprint	$ .50 to $1.00	Manual	Poor - Most source separated material is source collected.
Clean White Paper	$ .40 to $ .80	Manual	Almost zero - Fraction is small and mostly contaminated.
Glass - Mixed Coloured	-0-	Screened	No known markets presently exist.
Glass - Clear Colour Separated	$ .84 to $1.26	Manual	Poor - Cost of manually separating bottles, etc., is very high in comparison to possible returns. Secondary processing for colour separation is required. Known primary separation processes do not colour separate.
Ferrous Metals	$1.30 to $4.80	Magnetic	Poor - Technology for separation is good but product is mostly cans having too high a tin and lead content for use as scrap steel so that the only existing market is for copper leaching - a very small and specified market. To generate a product for the large scrap steel market, secondary processing is required.
Non-Ferrous Metals Mixture	extremely variable	Density	Fair - Primary separation processes provide a mixture of elements and alloys having high values. Manual selection of aluminum and copper and stainless offer a possibility of some economic return.
Rubber (mostly tires)	variable	Manual	Poor - Supply exceeds demand but the increasing price of raw rubber (20¢ to 47¢ per lb in 12 months) may alter this situation.
Plastics	-0-	Density	No existing market.
Organics and Putrescibles	-0-	Density	Zero - This fraction as obtained from a primary separation plant has no known market. Composting is considered as secondary processing and technology and equipment is quite varied.

15.3 POTENTIAL FUTURE MARKETS FOR COMMODITIES FROM A RECLAMATION PLANT

15.3.1 Commodity - Fuel

In its raw or unprocessed state, solid waste has a BTU content of approximately 5,000 BTU/lb.

It can, however, easily be processed to remove the non-combustibles, bringing its net BTU content up to about 8,000 BTU/lb.

Since firing in its raw form to recover energy as is done in numerous European incinerators is not new technology, we will consider the marketability only in the processed form as fibre fuel.

As obtained from the primary dry separation plant, (see Preliminary Layout 982-130-7), two possible fuel fractions become available.

1. Light Fuel Fraction - 8,000 BTU/lb - 95%
2. Heavy Fuel Fraction - 14,000 BTU/lb - 5%

"Light fuel" is defined as the shredded combustible component of solid waste, made up of organics and paper products but excluding, through air classification, the metals and heavier plastic materials.

"Heavy fuel" includes the Polyvinyl chloride and heavy plastic materials which substantially contribute to the higher BTU values.

Potential customers for the combined fuel fraction include:

Cement Plants - a Wet Kiln uses 2,700 BTU/lb cement

- a Dry Kiln uses 1,600 BTU/lb cement

Present fuels used by cement plants are natural gas, Bunker "C" oil, coal, waste oil. Studies done on a computer model by Ontario Research Foundation indicate that the light fibre fuel fraction is certainly compatible with the processing of cement and that the heavy plastics fraction can also be used.

Cement plants have indicated an interest in initiating a program to utilize the fuel fraction for up to 40% of their fuel requirements.

Industries having very large boiler plants may be able to use the combined fuel fraction up to a possible 15% of their requirements.

These would include - Power Plants

- Paper Companies

Where more than 15% of the fuel make-up is to be the combustibles from solid waste, it may prove advisable to use only the light fuel fraction.

15.3.1 (Cont'd)

Potential Customers for the fuel fraction include:

Meat Processing Plants

Vegetable Processing Plants

Tire Plants

Distilleries

Lumber Kilns

Brick Plants

Pre-requisites to Market acceptance of Fibre Fuel

1. Carry out full scale firing tests monitored to establish accuracy of firing rate, exhaust gases, particulate discharge, flame geometry.

2. Establish specifications that will enable the material to be utilized more widely as a fuel, e.g. minimum BTU content - minimum chlorides, sulphur.

Research has also been done in the conversion of Municipal Solid Waste to methane (1) gas and to oils (2) suitable for use as fuels.

Notes: (1) Syngas Process for conversion to methane and ethane has been patented but still requires a considerable amount of R & D.

(2) The Garrett Process for the conversion of solid waste to oil, funded by E.P.A. is being piloted. See under technology.

Potential Customers for gas and oil fuels

Gas companies with pipeline distribution.

Users of low grade fuel oil.

Pre-requisites to Market acceptance of Recovered Oils and Gas

1. Additional research and process development.
2. Process flow diagram and economic analyses.
3. Fuel Use Module, construction and operation for verifying technology, economics and product quality control.
4. Construction of full scale facility.

15.3.2 Commodity - Miscellaneous Paper

End use - newsprint and fine papers, tissue.

The market for newsprint is very large and presently is a sellers market. Traditionally this market fluctuates from an over supply situation to the opposite as demand and capacity chase each other in an endless spiral.

However, miscellaneous paper as recovered from solid waste cannot be used directly in news or fine papers without reprocessing, cleaning and possibly even bleaching.

Black Clawson's fibreclaim process segregates and recovers the longer high grade fibres and discards the balance amounting to 80% of the fibre.

15.3.2 (Cont'd)

Some research has been done to try and use all the fibrous or cellulose fraction and results have been very encouraging.

Potential Customers - Newsprint mills, fine paper mills, tissue mills.

Pre-requisites to Market acceptance of Recovered Papers

1. Additional research on process development.
2. Process flow sheet and economic analyses.
3. Paper Use Module, construction and operation for verifying technology, economics and product quality control.

15.3.3 Commodity - Ferrous Metals

End Use - remelt in steel mill as No. 2 scrap.

Much of the ferrous metal fraction consists of cans, and as such has had a high percentage coated with plastic and tin. These cans may have lead seams, zinc coatings, aluminum tops, etc.

No. 2 steel scrap must be free of tin, zinc and plastics and not be too severely oxidized.

Potential Customers - steel mills, scrap metal dealers.

Pre-requisites to Market acceptance of Ferrous Metals

1. Process flow sheets and economic analysis of the different methods of de-tinning and cleaning.

2. Removal of aluminum contamination.

3. Assurance to customers of quantity and quality of the product.

15.3.4 Commodity - Non-Ferrous Metals

Commodities - copper, lead, zinc, aluminum, nickel, stainless steel.

End Use - scrap or bar metal depending on the degree of purity obtained from processing.

The non-ferrous fraction of solid waste is a very complex mixture of relatively high grade material.

Potential Customer - scrap metal dealer, non-ferrous metal processors.

Pre-requisites to Market acceptance of Non-Ferrous Metals

1. Analyses and evaluation of present technology available for the best recovery process.

2. Research and development program to verify the technology, establish pilot operation and supply information for detailed engineering study.

3. Detailed engineering study and metals extraction module.

4. Build full scale plant.

15.3.5 Commodity - Glass

End Use - glass fibre, glass foam, glass wool, glass beads, insulation, containers.

15.3.5 (Cont'd)

The markets for both foamed glass insulation and fibreglass insulation are well established and large - particularly for the latter. The building industry can and will absorb much larger quantities of this material, particularly in the face of increased energy and fuel costs.

Since most fibreglass insulation is presently made from new glass, it should be possible to effect economies by using this reclaimed material.

Potential Customers - insulation manufacturers.

Pre-requisites to Market acceptance of Reclaimed Glass

1. Research and Development program to verify the secondary use technology.
2. Plant to manufacture product to standard.
3. Cleaning and colour separation.

Desirable Market Aid

Building codes to specify that new homes be built to minimum heat loss standards as an energy conservation measure.

15.3.6 Commodity - Reclaimed Rubber

End Use - tires, rubber goods.

Processes for de-vulcanizing rubber tires are in use at present but have in the past not been very economical because of the low prices of raw rubber. This has changed

dramatically in the last twelve months, the price going from 20¢/lb to 47¢/lb.

In the past, the economics of reclaiming rubber has been so poor that industries based on using discarded tires, obtained at zero cost, have had difficulty showing a profit.

Since this is a petro-chemical based product, the whole aspect of the reclamation of rubber could change quite drastically.

Potential Customers - Tire manufacturers

Black Rubber goods Manufacturers

Hose Manufacturers - Belt Manufacturers

Pre-requisites to Market acceptance of Reclaimed Rubber

1. Cleaning and metal separation.

15.3.7 Commodity - Plastics

End Use - shredded fuel used for generation of steam, power, heat.

- re-use in the plastics industry.

Plastics, when used as fuel, have a high BTU content but also generate corrosive gases (HCL and HF) from P.V.C. and Teflon. Consequently, markets that can use this material are those that can nullify their effect either by dilution or in the process of use.

15.3.7 (Cont'd)

(a) Plastics, particularly polyethylene and P.V.C. appear in a variety of colours making colour control difficult. Consequently, markets would be limited to those able to use the darker colours.

Potential Customers

1. Large solid fuel fired boilers where this material is fired as a small fraction of the total fuel.

2. Cement plants which can absorb and neutralize the chloride and fluorides.

3. Plastic pipe manufacturer.

4. Manufacturers of dark coloured plastic products.

Pre-requisites to Market acceptance of Reclaimed Plastics as Fuel

1. Design of feeding and mixing equipment and testing for controlling rate of firing.

2. Full scale long term firing tests in solid fuel fired boilers with complete monitoring of the effects on boiler tubes, dust collection equipment, stack and exhaust gases, ash handling equipment.

3. Full scale sustained firing tests in a wet cement kiln and in a dry cement kiln.

As Reclaimed Plastics

1. Further development of technology to extract the plastics from inerts and other undesirable materials so it can be used for plastic reclamation from solid waste.

2. Construction of a pilot plant to verify and expand the laboratory processes.

3. Construction of a full scale facility.

TABLE 15.3.8

POTENTIAL MARKETS

An assessment of potential economics, markets, products, and recovery techniques.

(a) Energy Conversion

Commodity or Material	Value/Ton Solid Waste	Recovery Method	Probability of economics being favourable
Light Combustible fraction (paper - sheet plastics)	$ 6.00 to $ 7.60	Air separation in Primary Dry Separation Plant	Excellent - Present indications are that a heat content of 8000 BTU per lb can be maintained within 3% range (as close or closer than coal). Participation by the cement industry is planned.
Heavy Combustible fraction (plastics, rubber, wood)	$ .30 to $ .40	By dry or wet separation	Good - If shredded and mixed with the light fraction, the possibility of utilization as fuel in a cement plant is good. This fraction could, however, cause corrosion in other large boiler units unless sufficient dilution is obtained by maintaining this fraction at a low level (10%).
Organics converted to Methane and Ethane by Gasification Processes	$ 5.50 to $10.00	From dry separation or wet separation plant with material dried	Fair - Conversion of organic fraction to Methane and Ethane involves complex secondary processing requiring cheap hydrogen. Economics depend on wholesale price of natural gas rising to $1.00/1000 CF. At 100% conversion rate, this plant must be supported on a differential of $2.00/ton of waste (7.60 + 40) U.S. $10.00 - less royalties.
Organics converted to a Combustible oil by Pyrolytic Processes	$10.50 to $15.30	From Dry Separation Plant or Wet Separation Plant with material dried	Poor - Conversion of organic fraction to a type of fuel oil with a pyrolytic process, leaves a maximum margin of $7.30 per ton of waste to amortize, operate and market the product. In its present form the product has no lubricating properties, which would prevent its being used in most existing equipment.
Organics - Pyrolysis	$ 5.50 to $10.00	From Dry Separation or Wet Plant dried	Almost zero - Mixture of tar and gas having a heat content of 500 BTU/CF would be a very difficult product to market. Natural gas as available will give 1000 BTU/CF.

(b) Fibre Recovery

Commodity or Product	Value/Ton Solid Waste	Recovery Method	Probability of economics being favourable
High grade fibre	$ 2.00 to $ 2.50	Reclaim of fibre through a re-pulping process Wet Separation	Fair - Fibre can be recovered from the primary separation plant but is gray and contaminated with food and plant waste. Balance of organics can still be used as fuel but must be dried to give the combustible fraction sufficient value to allow it to be transported or to be raw material for either the Gasification or Pyrolysis Process.
Groundwood substitute for Newsprint	$37.00 to $65.00	Dry or Wet Separation and Secondary Chemical Processing	Excellent - Some research has been done in which the organic fraction has been treated to remove food waste and all materials except cellulose fibre. The possibility of the resulting product being used as a substitute for groundwood in newsprint, or for tissue is very good. This is a long term project requiring additional lab work, piloting and then scaling up to a full scale plant. Considerable interest has been expressed by a paper producer.

TABLE 15.3.8

(c) Inorganic Recovery

Commodity or Product	Value/Ton Solid Waste	Recovery Method	Probability of economics being favourable
Fibreglass insulation	$ 4.00 to $ 5.00	Dry Separation Thermal Process	Fair - Economical if little or no charge made for waste glass and a minimum of $50.00 per ton obtained for product.
Foamglass insulation	$ 6.00 to $ 8.00	Dry Separation Chemical and Thermal Process	Fair - Economical if little or no charge made for waste glass.
No. 2 Scrap Steel	$ 4.00 to $ 8.10	Dry Separation plus Chemical	Excellent - Present de-tinning technology can recover both tin and steel. A minimum of 12,000 tons/year is required to justify a plant (200,000 T/yr Solid Waste).
Non-Ferrous Metals	$ 8.00 to $10.00	Dry Separation Mechanical Process	Good - Two metallurgical processes have been developed to recover these materials. Being in the laboratory stage they require piloting and refining.
Reclaimed Rubber	$ 4.00 to $ 6.00	Dry Separation Mechanical Chemical Process	Fair - Value/ton waste is not high but separation is simple technology and is fully developed - cost of new rubber will determine the economics of reclamation.

(d) Other Organic Recovery

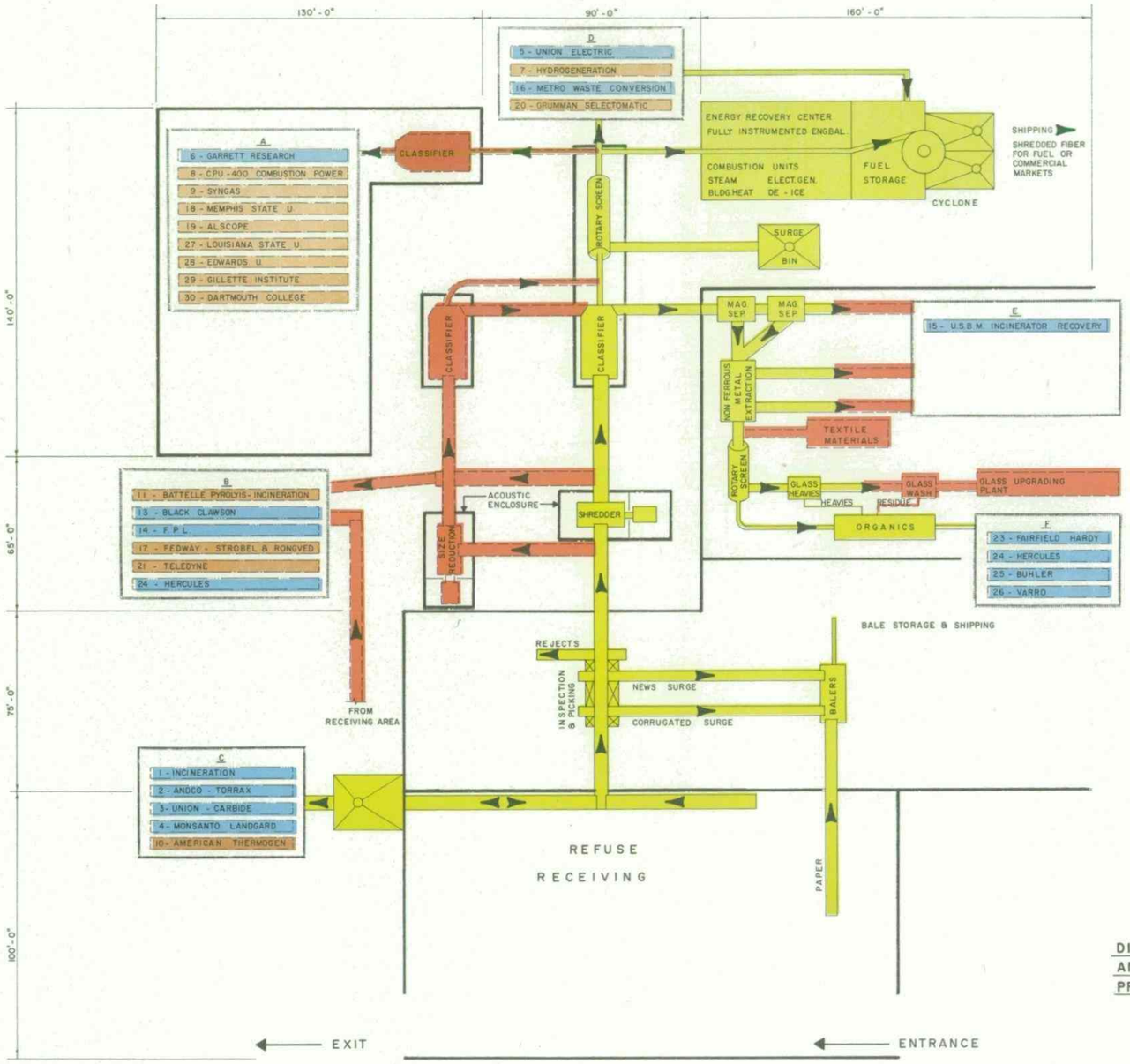
Commodity or Material	Value/Ton Solid Waste	Recovery Method	Probability of economics being favourable
Synthetics and Plastics	$13.00 to $21.00	Solvent extraction	Good - Solvent extraction processes have been developed recently by plastics manufacturers to achieve 100% utilization of their own waste. Two of these appear to be adaptable for recovering plastic values from solid waste, particularly PVC and polyethylene.
Compost and Fertilizer	-0-	Aerobic Digestion	Poor - The history of failures of compost producing plants is lengthy largely because chemical fertilizers give greater crop returns at less over all cost. Compost has possible value as landfill or cover, allowing improved social acceptance of such sites.

From the foregoing analysis of existing and potential markets for reclaimed products, it appears that a dry separation and reclamation system can provide commodities for the greatest number of markets.

SECTION 16

TECHNOLOGY

982-130-8



EXISTING PROCESSES AND CONCEPTS

RECOVERED PRODUCTS	ENERGY RECOVERY 1	2	3	4	5	6	7	8	9	10	11	12	MATERIAL RECOVERY 13	14	15	16	17	18	19	20	21	22	COMPOST 23	24	25	26	CHEMICAL 27	28	29	30	34
	INCINERATION	ANDCO - TORRAX	UNION CARBIDE	MONSANTO LANDGARD	UNION ELECTRIC	GARRETT RESEARCH	HYDROGENERATION	CPU-400 COMBUSTION POWER	SYNGAS	MEMPHIS STATE U.	ALSCOPE	BATTELLE PYROLYIS-INCIN.	BLACK CLAWSON	FEDWAY - STROBEL & RONGVED	TELEDYNE	HERCULES	FAIRFIELD HARDY	HERCULES	BUHLER	VARRO	BOWLER	LOUISIANA STATE U.	EDWARDS U.	GILLETTE INSTITUTE	DARTMOUTH COLLEGE	U.S.B.M. INCINERATOR RECOVERY	AMERICAN THERMOGEN	F P L	SYNGAS	METRO WASTE CONVERSION
STEAM	X	X	X				X						X																		
ELECTRICITY	X			X			X																								
FUEL GAS		X		X			X		X																						
FUEL OIL				X	X																										
FIBER (FUEL)				X										X		X															
FIBER (P'ULP)													X	X		X	X	X													
Fe METAL	X		X	X	X		X	X					X	X	X	X	X	X					X	X	X	X					
NON Fe METAL													X	X		X	X	X					X	X	X	X					
GLASS				X			X						X	X		X	X	X					X	X	X	X					
SLAG CHAR	X	X	X	X	X	X	X		X		X	X																			
AGGREGATE																															
YEAST													X													X					
PROTEIN																							X								
FATS																								X							
ALCOHOL																									X						
GLUCOSE																										X					
CATTLE FEED																	X						X								
COMPOST													X						X	X	X	X		X							
RUBBER																															
	C	C	C	C	D	A	D	A	A	C	B		B	B	E	D	B	A	A	D	B		F	B	F	F	A	A	A	A	

ABOVE PROCESSES OR CONCEPTS MAY FIND FUTURE APPLICATION IN A RECLAMATION PLANT (SEE PROCESS No.)

LEGEND:

- INITIAL INSTALLATION
- FUTURE POSSIBLE INSTALLATION
- PROBABLE BUILDINGS
- KNOWN TECHNOLOGY
- DEVELOPING TECHNOLOGY

DIAGRAM SHOWING WHERE KNOWN TECHNOLOGY AND DEVELOPING TECHNOLOGY COULD FIT INTO THE PROPOSED EXP. WASTE RECLAMATION PLANT.

THIS DRAWING WAS PREPARED BY KILBORN ENGINEERING LTD. FOR THE EXPERIMENTAL WASTE RECLAMATION PLANT OF THE MINISTRY OF THE ENVIRONMENT, WASTE MANAGEMENT BRANCH AND MAY NOT BE USED FOR ANY OTHER PROJECT EXCEPT WITH PERMISSION IN WRITING FROM KILBORN ENGINEERING LTD.

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CLIENT: ONTARIO MINISTRY OF THE ENVIRONMENT.
LOCATION: TORONTO. CANADA.
KILBORN

TITLE: 200 T/D EXPERIMENTAL SOLID WASTE RECLAMATION PLANT. TECHNOLOGY APPLICATION.

AGCT. No. | PROJECT No. 982 | DIVISION No. 15 | DRAWING NUMBER 982-130-8 | REV.

TECHNOLOGY

16. GENERAL

Technological development has been rapid so that information is quickly dated. The assessments which follow are useful only as a comparison of waste management recovery systems.

The technology for resource recovery has been carefully examined in relation to principal and secondary products recovered, size of facility, capital cost, operating cost, revenue produced, net costs, and has been divided into two basic groups.

Group 1, consisting of processes that have been piloted or have had demonstration plants built, is categorized as known technology.

Group 2, consisting of processes that are in the laboratory or bench scale stage, is classified as developing technology.

Resource Recovery processes have been divided into four categories:

1. Energy Recovery Processes.
2. Composting Processes.
3. Material Recovery Processes.
4. Chemical and Miscellaneous Processes.

16. (Cont'd)

Incinerators recovering steam or generating power and pyrolysis processes of all types which recover energy values in one form or another have been listed under energy recovery processes.

The following does not represent a bibliography of processes, but is a representative sampling of the technology available. (See Drawing No. 982-130-8).

This cross-section of known and developing technology provides the basis for the operational flexibility incorporated in the design concepts of the proposed experimental waste reclamation plant.

The experience and data obtained from operating energy recovery processes that generate steam, indicate that if greater benefits are to be obtained, it will be in fuel conversion, material recovery or chemical processing. All of these require separation of the various components, thereby indicating a requirement for a primary separation process.

There are two methods of effecting primary separation, these being:

(1) Wet Separation

(2) Dry Separation

Since fifteen of the processes listed require dry separation and only six can use wet separation, we

recommend a dry primary separation plant, particularly since it is a simple matter to add water at any stage.

Following is a brief description of a wet separation process and a dry separation process and a categorized list of most of the known processes, summaries of each of them, and a synopsized description of each.

16.1 PRIMARY SEPARATION PROCESSES

16.1.1 Wet Separation

Description

The Wet Separation System involves size reduction, addition of water in a hydrapulper, separation of the fibrous material from the heavy fraction in the hydrapulper and a further cleaning, screening, etc., to recover the paper fibres.

Most of the water is recirculated, organics can either be composted, incinerated with or without steam recovery, or landfilled, leaving glass, ferrous metals and non-ferrous metals for secondary processing.

Ferrous metal is magnetically separated, glass and plastics are separated by elutriation.

Advantages

Equipment is reliable with technology being reasonably well advanced (Black Clawson Franklin Ohio Plant).

16.1.1 (Cont'd)

Recovered Ferrous Metals are clean and not balled or crushed so they can be used as feedstock for a de-tinning plant.

Recovered glass is clean and a fair percentage is large enough to allow optical colour separation.

Non-ferrous metals are clean and ready for reprocessing.

The process allows the recovery of fibre for re-use in the paper industry with the balance of the organic material available as fuel. Very little odour is generated by the process.

Disadvantages

Wet separation requires the use of large quantities of water (a 1000 T/D plant would circulate approximately 6,000,000 gallons of water per day). This water has an extremely high B.O.D. and may require some treatment if the system is operated continuously without a bleed-off to the sanitary sewage system.

The greatest disadvantage of wet separation is that once the water is added, it is impossible to mechanically dewater paper stock to greater than 45% - 50% dryness.

While this does not prevent the material from being utilized as a fuel, it does reduce its heat value to

about 3500 BTU/lb. Transportation then becomes a major consideration since 50% of the material being transported is water, thereby reducing its value as a fuel, particularly when compared to coal having a heat value of 11,500 BTU/lb, and costing $13.00/ton.

16.1.2 Dry Separation

Description

Dry separation requires size reduction and uses a combination of screening and air classification to separate paper and light fractions from ferrous metals, non-ferrous metals, glass and other heavy materials.

The air used for air classification performs the function of drying as well as dust control and collection. Ferrous metals are magnetically separated and the non-ferrous fraction is separated from glass, plastics, and food and plant waste by elutriation which also cleans the glass and metals.

Advantages

Technology is well advanced, with recovered light fractions having a heat content of about 8000 BTU/lb. The light fraction is relatively free of Polyvinyl Chloride because of its higher density so that when used as a fuel, the problems of HCL formation are eliminated.

16.1.2 (Cont'd)

Air separation automatically provides a classifying system that ensures a product that lends itself to pneumatic transport and feeding.

Dry separation also allows the recovery of fibre for further use in the paper industry.

Ferrous metals are clean and can be used as feedstock for de-tinning and steel recovery.

Non-ferrous metals are clean and ready for reprocessing.

Heavy plastics are separated for possible further use.

With the fibre fraction at 92% dryness, and a heat content of 8000 BTU/lb, a much wider transportation radius is within the economic scope of the material.

Very little odour is generated by the process.

Disadvantages

All of the known technology has not been put together as a full operating unit.

Glass is battered into fragments too small to allow economical colour separation by known technology.

16.2.1 Energy Recovery Process

Known technology.

Included in this category is:

(a) Conventional Incineration, where the heat output is utilized to produce steam and in turn electricity. Includes;

Des Carriers Incinerator - Montreal
Issy-Les-Moulineaux Incinerator - Paris
Edmonton Incinerator - London

(b) High Temperature Incineration, where total destruction of the waste takes place, but heat is recovered to produce steam. Includes;

Andco - Torrax Process
Union Carbide Process
Monsanto Landgard Process

(c) Fibre Fuel, where the waste is prepared as a fibre material and burned as a supplement in a conventional heating plant. Includes;

Union Electric Co. Process

(d) Pyrolysis, where the waste is reduced by pyrolytic action and a fuel oil material is recovered. Includes;

Garrett Research Process

See Drawing No. 982-130-8.

TABLE 16.2.1

SUMMARY OF RESOURCE RECOVERY PROCESSES

Energy Recovery Processes - Known Technology

Name and Location	Principal Product	Other Products	Capacity (Tons/Day)	Capital Cost ($/Ton/Day)	Operating Cost ($/Ton)	Revenue ($/Ton)	Net Costs ($/Ton)	Preliminary Separation Required Wet or Dry	Development Status
1. Des Carriers Montreal Incinerator, Montreal, Quebec	Steam	Ferrous Metals	1200 (N) 900 (A)	12,500	7.00	3.50(N) -0- (A)	3.50 9.30	NONE	Plant in operation since 1970.
2. Issy-Les-Moulineaux Paris, France	Steam Electricity	Scrap Residue	1800 (N) 1500 (A)	15,300	7.70	2.88	4.82	NONE	Plant completed in 1965.
3. Edmonton Incinerator London, England	Steam Electricity	Ferrous Metals Clinker	1825 (N) 1450 (A)	13,000	9.80	2.55	7.25	NONE	Completed in 1971.
4. Torrax - Hi Temperature Incinerator North Tonawanda, N.Y.	Steam	Slag	600	11,500	8.81	2.40	6.41	NONE	75 T/D demonstration plant in operation since 1970.
5. Union Carbide Tarrytown, N.Y.	Fuel gas or steam	Slag	100-(Estimated)	9.450	9.10	4.00	5.10	NONE	5 T/D pilot plant in operation since 1971 - 2000 T/D demonstration plant proposed.
6. Landgard - Monsanto St. Louis, Missouri	Steam	Ferrous Metals Aggregate	1000	15,000	9.58	4.67	4.91	NONE	35 T/D pilot plant in operation since 1969 - 1000 T/D demonstration plant under construction for Baltimore.
7. Union Electric St. Louis, Missouri	Fuel Metals	Ferrous Metals	650	11,000	N/A	N/A	N/A	DRY	650 T/D demonstration plant in operation since 1972 - modified in 1973.
8. Garrett Research Laverne, California	Oil (Fuel)	Ferrous Metals Glass	200 (Proposed)	6,960	6.99	5.84	1.15	DRY	4 T/D pilot plant completed in 1972.

"N" indicates nominal capacity.

"A" indicates actual operating conditions.

16.2.1.1 Montreal Des Carriers Incinerator

Description

The Montreal Incinerator, with its boiler installation, represents an energy recovery system. It is a Von Roll design in use in Europe since 1954. Other similar units are under construction or have been completed in Hamburg, The Hague, Frankfurt, Vienna, Nuremberg, Basel and Tokyo. Under continual refinement, this unit represents the most up-to-date design of its type.

The plant has four units each capable of processing 300 T/D of refuse or 1200 T/D total. This capacity is, however, nominal, its true capacity being 900 T/D with one unit for servicing.

It is a completely enclosed integrated system for disposing of municipal waste. Material is trucked to the incinerator site by the city collection vehicles, weighed and then delivered to a storage pit. Operators direct the drivers to the proper dumping location by signal lights. The pit has a storage capacity of 2500 tons, enough to allow operation over weekends when nothing is delivered.

The waste handling area is totally enclosed so that all dust and odours are controlled by fans giving a slight negative pressure in the dumping area.

16.2.1.1 (Cont'd)

The feed hoppers which are across the pit from the dumping area are fed by two pit cranes which automatically weigh-load the amount of waste in each bucket load. Oversize materials are either shredded or crushed and discharged back into the storage pit to be incinerated in a subsequent charging load.

Crane operators, in a glass enclosed air conditioned booth can mix the material in the pit for greater homogeneity of the boiler feed. A vibrating feeder under the feed hopper uniformly feeds the furnace. The furnace is completely sealed, allowing positive control of burning rate.

Grates are Von Roll slightly inclined from end to end. Waste dries on the uppermost grate, starts burning on the second and incineration is relatively complete on the third. These grates have been the subject of progressive component improvement. Each grate is moved by a hydraulic motor helping to achieve more complete burning and also moving the material along the grates. The burned out residue and non-combustibles drop into two parallel water-filled troughs running the length of the incinerator units.

A wet drag chain conveyor carries the residue to a rotary screen where metals, etc., can be salvaged and

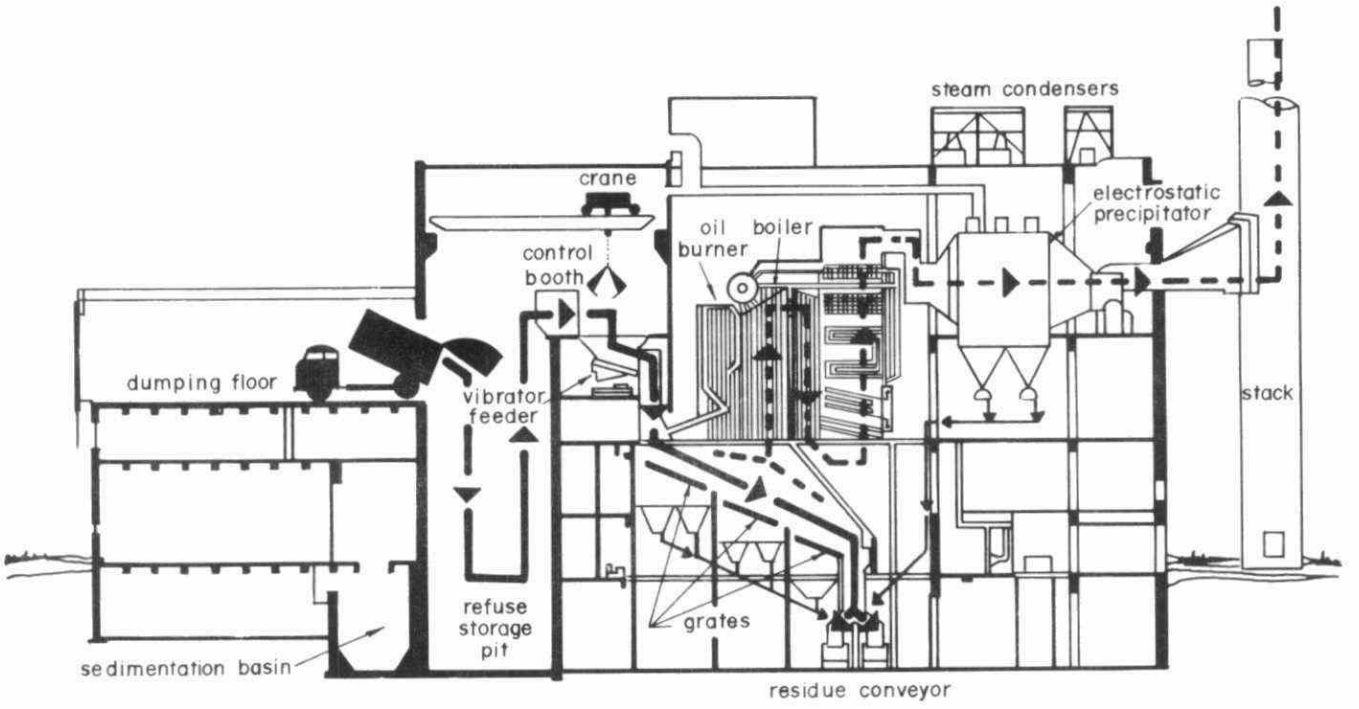
inerts landfilled. Quench water is run into sedimentation ponds and recirculated.

The boilers serve to convert the waste heat to steam and lower the gas temperatures to the operating range of the electrostatic precipitators that remove the fly ash.

The boilers are one drum Eckrorh units having a radiant section, a convection section, a superheater, air heater and economizer. The front section has a water cooled combustion chamber with a down firing oil burner using Bunker C fuel. The oil flame is kept separate from the refuse flame, the gases being mixed before delivery to the boilers. Temperatures are kept below 1900^{o}F to avoid melting the refuse cake.

The lower furnace sidewalls are silica carbide brick with no water cooling.

Exhaust gas temperatures are approximately 480^{o} - 485^{o}F and are cleaned by electrostatic precipitators and are exhausted from two 250 ft chimneys. Burnout is better than 99.5%. Particulate emission is approximately .17 lb per 1000 lbs gas or .005 gr/C.F. - Incinerator Residue Volume is approximately 15% of the original.



MONTREAL DES CARRIERS INCINERATOR 16.2.1.1

16.2.1.2 Issy-Les-Moulineaux Refuse Burning Power Generation Plant
Paris, France.

Description

The plant, which was built in 1965 has a capacity of 1500 T/D (1360 metric tons) operating 24 hrs/day, 7 days/week. There are four incinerator units, each with a capacity of 450 T/D, (409 metric tons), each operating eleven months out of twelve. Shut-downs are arranged so that three units operate in the summer and four in the winter.

Material is unloaded into a refuse receiving pit of 212,000 cu ft (6000 cubic metres), transferred into furnace feed chutes by two overhead travelling cranes, each carrying a 6½ cu yd bucket (5 cubic metres).

Grates are Martin reverse acting stepped type. At the end of the grate, an extracting roller moves the material into a water-filled ash pit. The depth of the combustion bed is controlled by varying the speed of the roller.

The ash pit residue is pushed onto a drip dry platform and then onto a conveyor that carries it to storage. Ferrous metals are magnetically extracted and marketed.

16.2.1.2 (Cont'd)

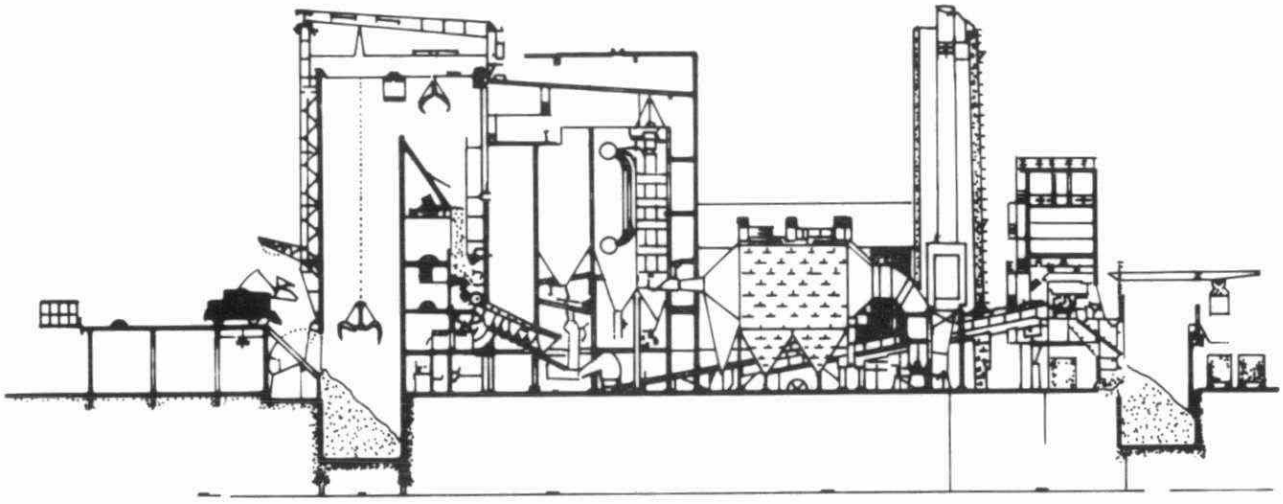
The boilers are water wall header type having a free gas passage in the first two chambers. Gases then pass into the superheater and the evaporator tube nest to produce steam at 927 psi - 770°F.

Two turbo-alternators, one of 9000 kilowatts and one of 16,000 kilowatts capacity are used to generate electric power. The first is a back pressure type that lowers the steam pressure from 725 to 232 psi, the second is a conventional type operating with a condenser. During the heating season, steam is by-passed from the exhaust of the back pressure turbine to a municipal piping network.

Exhaust gases are cleaned in an electrostatic precipitator and discharged through a 263 ft smoke stack. Particulate discharge is maintained at a low enough level to avoid any visible smoke plume.

Steam yield from the boilers has been 3540 lbs/ton of waste incinerated.

Capital Cost of the plant was $23,000,000.00 on an operating basis of 550,000 tons/yr, the cost per ton less operating revenue, but not including capital charges is $4.82 per ton.



ISSY - LES MOULINEAUX POWER GENERATION PLANT
PARIS FRANCE

16.2.1.3 Edmonton Refuse Burning Power Generation Plant London, England.

Description

The plant which has a capacity of 1450 T/D (1330 metric tons) operates 24 hrs a day, 7 days per week and accepts an actual daily tonnage of 2000 T/D for five days. There are five units, each having a capacity of 365 T/D. Four are normally in operation with one on standby. Delivery of material is concentrated between 10:00 a.m. and 4:00 a.m. in approximately three ton loads. The material is unloaded on one of twenty-three unloading bays which gravity discharge into the five bunkers having a total storage capacity of 4300 tons (460,000 C.F.).

Refuse is transferred from the bunkers by two overhead grab cranes into furnace feed chutes and pushed onto grates by hydraulic rams. Each crane has a minimum feed rate of 31 tons per hour. A third operates on partial standby service.

The combustion chamber is designed around a VKW stepped roller grate consisting of an inclined series of seven parallel hollow rollers, 5 ft in diameter and 11 ft 6 in. long, each driven through a variable speed drive and rotating at ½ to 5 revolutions per hour.

16.2.1.3 (Cont'd)

Primary air is fed through the rollers and temperature of conbustion caused by the burning refuse turning and falling from roller to roller results in complete combustion.

Burnt clinker and ash falls from the last roller through a quenching bath onto conveyors that carry it to the residue storage area. Hot gases generate steam in a water tube boiler.

Steam is used to drive three of four 12.5 megawatt turbogenerators delivering approximately 35 megawatts into the power grid. In addition two 2.5 megawatt sets supply in-house power requirements.

A steam pressure governing system is used to maintain line pressure because boiler firing rate must be regulated. A dump condenser condenses excess steam that may be produced over the turbine capacity. Circulating water for the condenser is run through an induced draft evaporating tower capable of a 15^{o} temperature drop to two million gallons of water per hour. Make-up water of approximately 1,000,000 gal/day is obtained from sewage plant effluent.

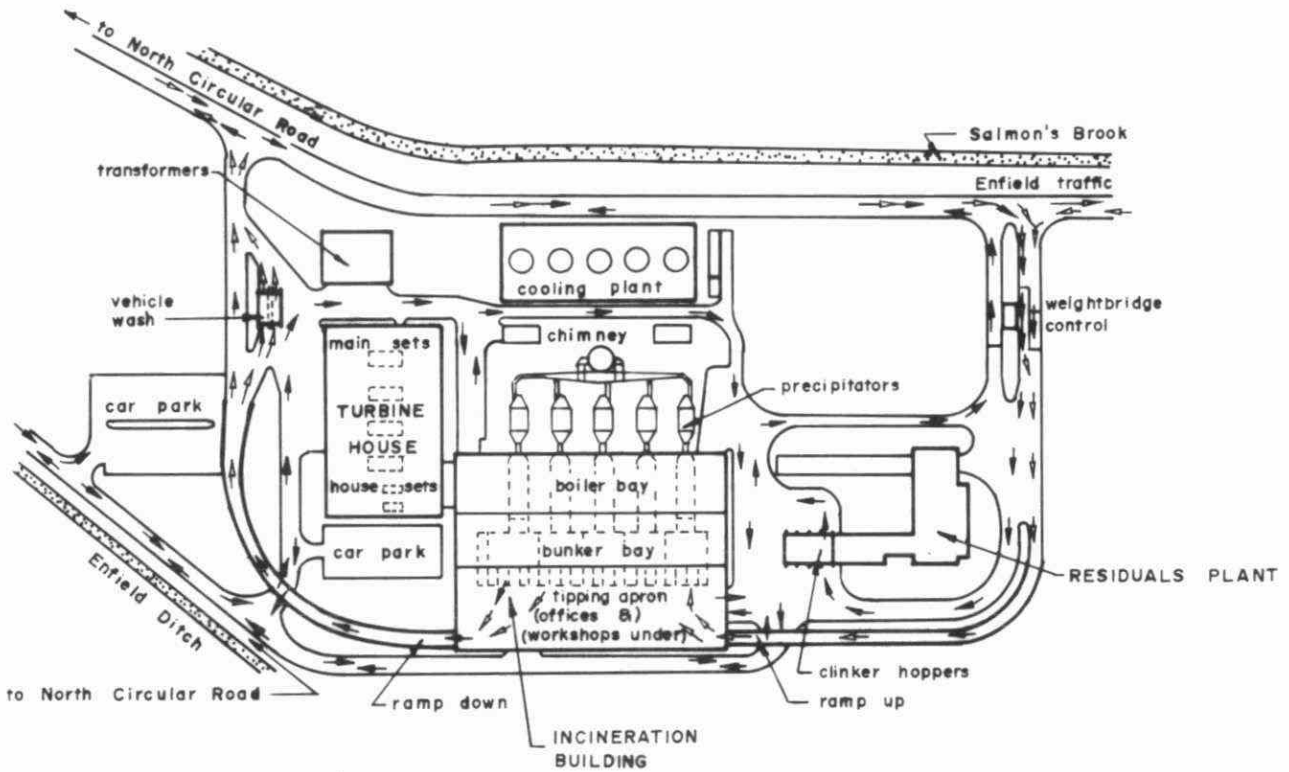
Power is generated at 11 KV and transformed up to 33 KV. Exhaust gases are cleaned in an electrostatic precipitator.

The main product is Power (25 - 30 megawatts (continuous) Ferrous Metals and Clinker are recovered - Residue of 125 T/D is landfilled. The capital cost of the plant was approximately $26,000,000.00 and it has been in operation since 1971.

At full capacity the costs per ton less operating revenue, but including capital charges, are $7.25/ton.

If for any reason input drops to 8000 tons/week, cost per ton becomes $12.10. Further reduction in input increases costs in proportion.

THE SITE LAYOUT

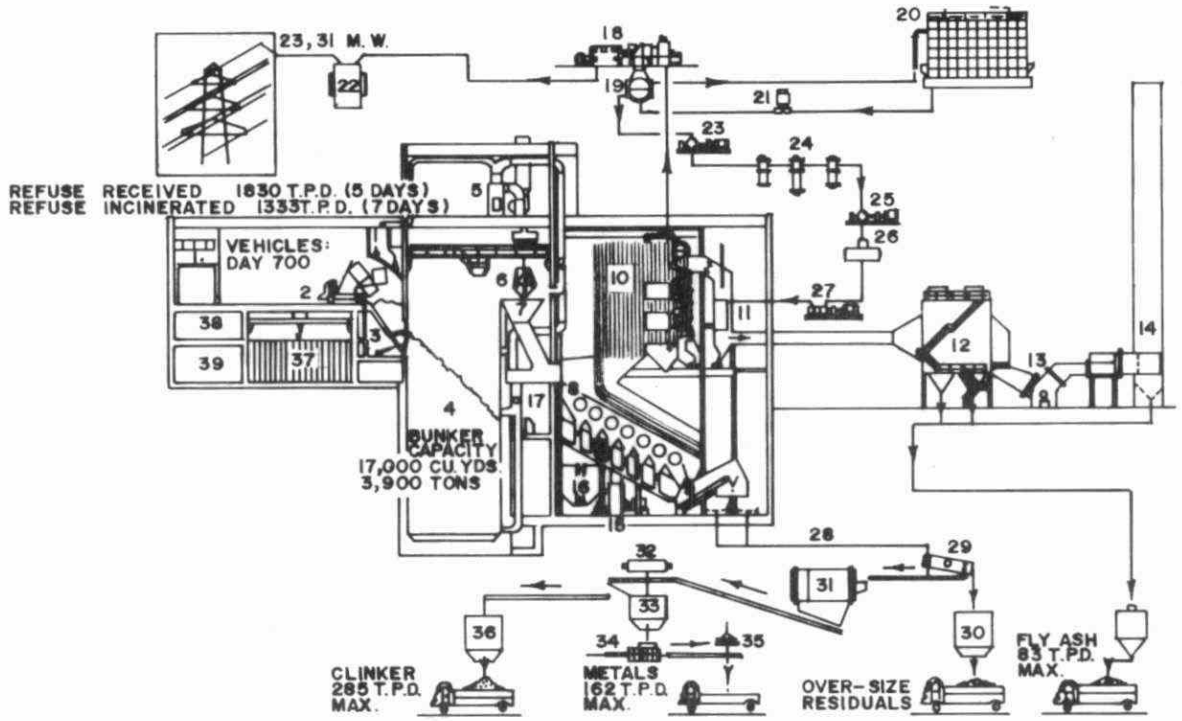


Refuse collection vehicles
Residuals transporters
Domestic site vehicles

Scale

0 200 400 600 800 1000 Feet

EDMONTON REFUSE BURNING POWER GENERATION PLANT
LONDON, ENGLAND



KEY

1 CONTROL ROOM
2 TIPPING APRON
3 TRIMMING DOOR
4 REFUSE BUNKER
5 DUST EXTRACTION PLANT
6 GRAB CRANES
7 BOILER FEED CHUTE
8 GRATE
9 CLINKER QUENCHING BATH
10 BOILER
11 ECONOMISER
12 ELECTROSTATIC PRECIPITATOR
13 INDUCED DRAUGHT FAN
14 CHIMNEY
15 FORCED DRAUGHT FAN
16 STEAM AIR PRE-HEATER
17 BOILER INSTRUMENT PANEL
18 TURBO-GENERATOR
19 CONDENSER
20 INDUCED DRAUGHT COOLING PLANT
21 C.W. PUMPS
22 TRANSFORMER
23 EXTRACTION PUMP
24 L.P. HEATER & DRAIN COOLERS
25 DEAERATOR LIFT PUMP
26 DEAERATOR
27 BOILER FEED PUMP
28 MAIN RESIDUALS CONVEYOR
29 VIBRATING SCALPER SCREEN
30 OVER-SIZE RESIDUALS HOPPER
31 ROTARY BREAKER SCREEN
32 MAGNETIC SEPARATOR
33 LOOSE METALS HOPPER
34 METAL BALING MACHINE
35 MAGNET CRANE
36 CLINKER HOPPER
37 WORKSHOP
38 ADMINISTRATION
39 FLY ASH SILO

EDMONTON REFUSE BURNING POWER GENERATION PLANT

LONDON ENGLAND

16. 2. 1. 3.

16.2.1.4 Andco - Torrax
51 Anderson Road,
Buffalo, New York. 14225

The Torrax System is basically a high temperature incinerator recovering steam from burned gases and a combined metal-glass slag which has little value but is quite inert.

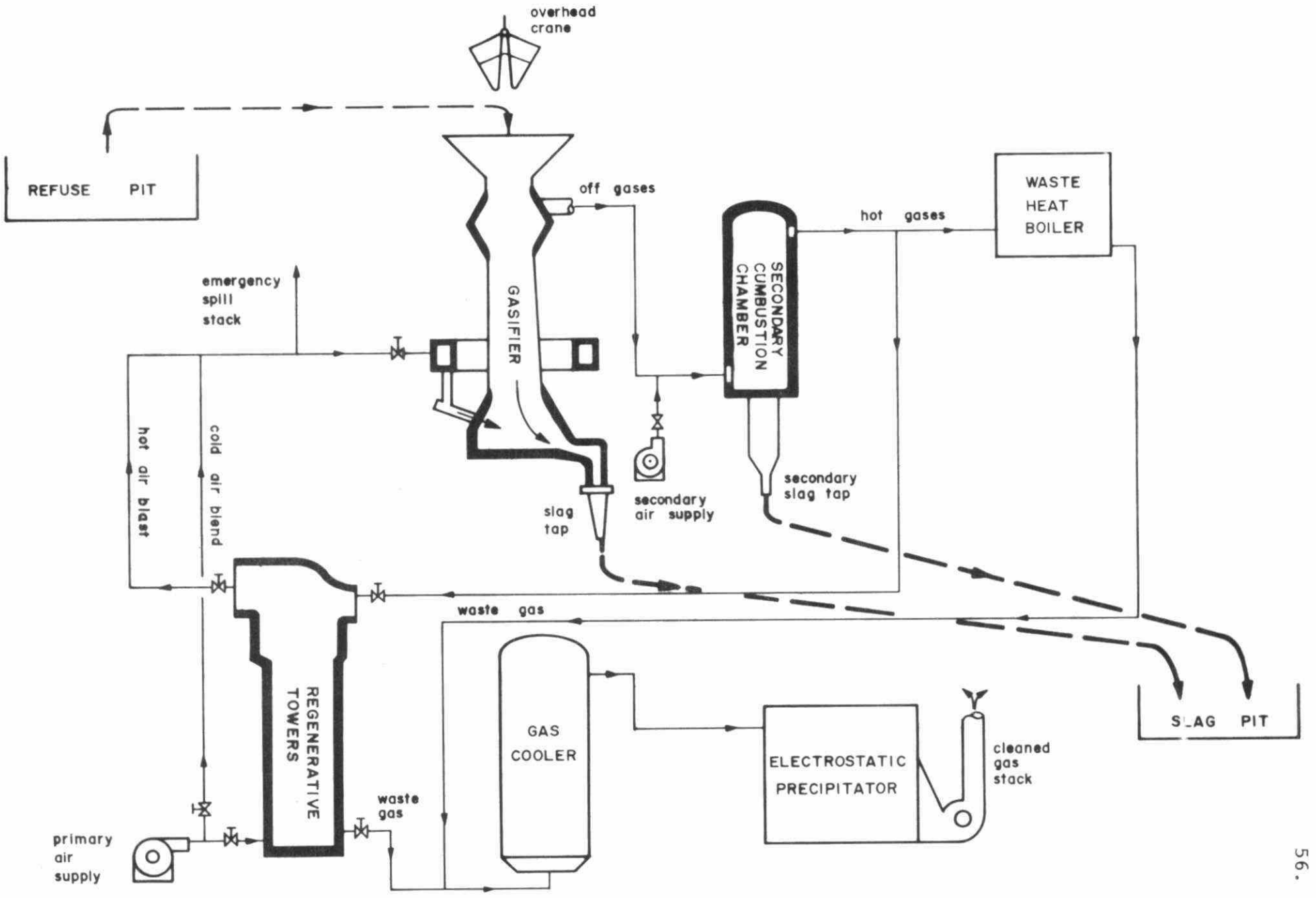
Refuse as received is charged into the top of the Gasifier which is a water-cooled vertical shaft furnace without grates. Hot gases permeate up through the refuse converting readily combustible materials into a gas which is completely burned in the Secondary Combustion Chamber. Non-combustible materials (metals, glass) settle down to the high temperature zone (2600^{o}F) at the base of the Gasifier and are melted in the intense heat. This liquid slag flows from the Gasifier into a water chamber where it is cooled and granulated into a sterile aggregate.

In the Secondary Combustion Chamber the gases from the Gasifier are burned above 2000^{o}F and some of the hot air passes to the regenerators. This reheated air may be directed back to the Gasifier. An inorganic slag flows from the base of the Secondary Combustion Chamber into a water quench. The heat not required by the Gasifier may pass into a gas cooler to generate steam.

16.2.1.4 (Cont'd)

Exhaust gases pass through an electrostatic precipitator or scrubber emission control system before release to the atmosphere.

Andco-Torrax has a 75 T/D plant operating and is now looking for commercial applications for the process.



ANDCO – TORRAX SYSTEM

16.2.1.4

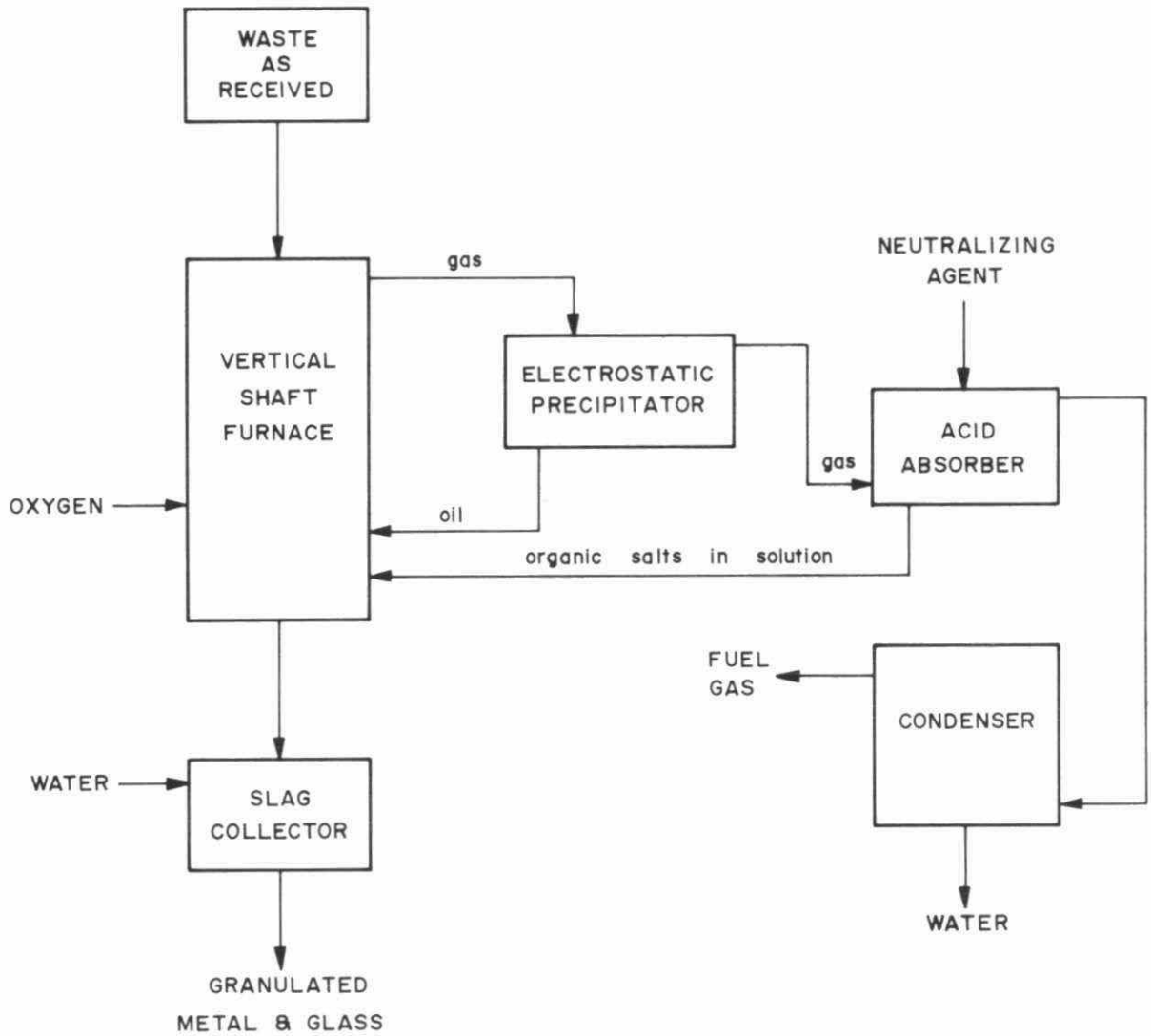
16.2.1.5 Union Carbide Corporation
Tarrytown, New York.

The Union Carbide development is basically a high temperature incinerator utilizing oxygen in place of air to develop high temperatures in the melt zone. A vertical shaft furnace is used into which all municipal waste can be fed directly. Gaseous oxygen is fed continuously into the bottom of the furnace. The molten slag formed by the high temperature in the bottom of the furnace is tapped continuously and quenched in water. As with high-temperature incinerators, the Oxygen Refuse Converter is a disposal system rather than a resource recovery system although the off gases may be cleaned for use as a fuel gas having a heating value about one-third of that of natural gas.

Steam and/or electrical power can, of course, also be produced.

The slag has little or no value, but is quite inert.

A 5 T/D pilot plant has been in operation in Tarrytown, New York, since early 1971. A 200 T/D demonstration plant is proposed.



UNION CARBIDE PROCESS

OXYGEN REFUSE CONVERTER

16.2.1.5

16.2.1.6 Monsanto Enviro-Chem Systems Inc.
800 North Lindbergh Boulevard,
St. Louis, Missouri. 63166

The primary objective of the Monsanto process is the disposal of municipal solid waste, reducing to a minimum the amount going to landfill.

The process known as the "Landgard" system encompasses the conventional operations for receiving and handling. The waste as received is first shredded and conveyed to storage. From storage it is fed continuously into a rotary kiln reactor. The kiln is refractory lined and of such a shape that waste enters one end and direct fired fuel oil enters the opposite end. Counter-current flow of gases and solids expose the feed to progressively higher temperatures as it passes through the kiln so that first drying and then pyrolysis occurs. The residue is exposed to the higher temperature just before it is discharged from the kiln into a water-filled quench tank where it is conveyed to a flotation separator.

Light material floats off as carbon char slurry and is thickened and filtered to remove water. Carbon char is conveyed to storage and disposal. Clarified water and filtrate are recycled for re-use. Heavy material is conveyed from the bottom of the flotation separator to a magnetic separator for removal of iron. Ferrous metal may be deposited in storage for removal. Balance

16.2.1.6 (Cont'd)

of the heavy material which includes a glassy aggregate is screened and stored.

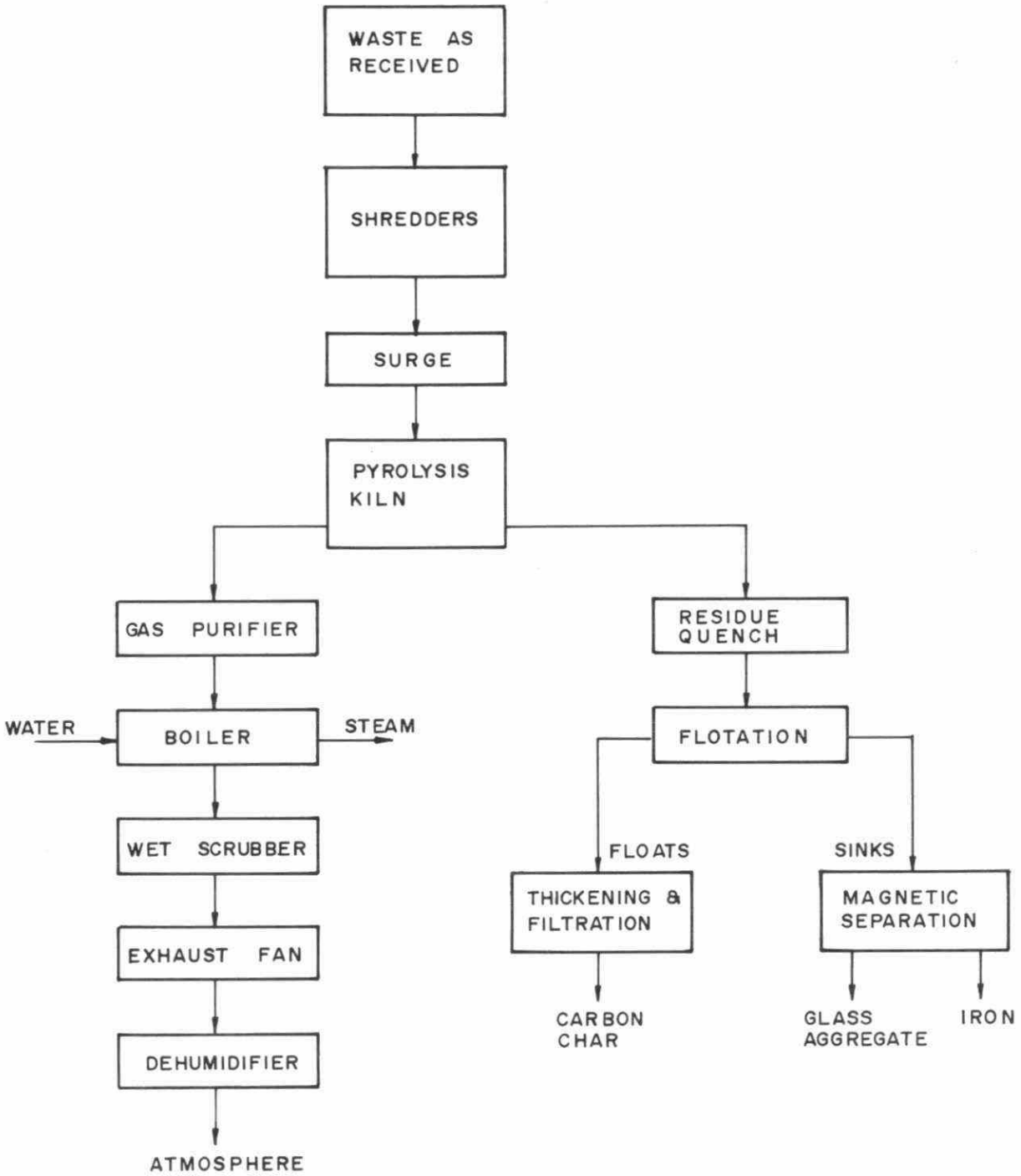
Pyrolysis gases are drawn from the kiln into a refractory lined gas purifier where they are mixed and burned. Hot combustion gases from the gas purifier pass through water tube boilers where heat is exchanged to produce steam. Exit gases from the boilers are further cooled and cleaned of particulate matter as they pass through a water spray scrubbing tower.

Scrubbed gases enter an induced draft fan which provides motive force for moving gases through the entire system. Gases exiting the fan are saturated with water and are passed through a dehumidifier to be cooled. Solids are removed from the scrubber by diverting part of the recirculated water to a thickener.

Underflow from the thickener is transferred to the quench tank, while the clarified overflow stream is recycled to the scrubber.

The plant can generate steam and recovers char, metals, and aggregate.

A 35 T/D pilot plant has been in operation since 1969 and a 1000 T/D demonstration plant is being constructed in Baltimore, Maryland, for start-up late 1974.



MONSANTO "LANDGARD" PROCESS

16.2.1.6.

16.2.1.7 Union Electric Company
Meramec Station, St. Louis, Missouri.

Horner and Shifrin Inc.,
5200 Oakland Avenue,
St. Louis, Missouri.

The Horner and Shifrin Fuel Recovery Process for the recovery of fibre fuels and metals is operating as a demonstration plant capable of handling 650 tons of refuse per day (2 shifts). It is located adjacent to an idle St. Louis incinerator, some 18 miles from the Power Plant which uses the fibre fuel it produces as a supplement to coal firing.

The raw refuse is discharged from packer trucks onto a receiving floor at the Recovery Plant where it is pushed to a receiving conveyor by front end loaders. From the receiving conveyor the refuse is discharged to a belt conveyor and then a vibrating conveyor which feeds the hammermill.

The hammermill, which reduces material to about one inch in size, discharges to a vibrating conveyor which feeds a belt conveyor leading to a Rader air classifier. The light fibre fraction is lifted by air from the top of the air classifier and is deposited on a belt conveyor which leads it to the storage bin. The heavy material coming from the bottom of the air classifier is separated magnetically, with the ferrous materials being sold and

16.2.1.7 (Cont'd)

the balance going to landfill.

The fibre material is removed from the storage bin by means of traversing floor augers travelling the length of the bin. This material is hauled by truck to the Meramec power generation plant some 18 miles from this processing plant.

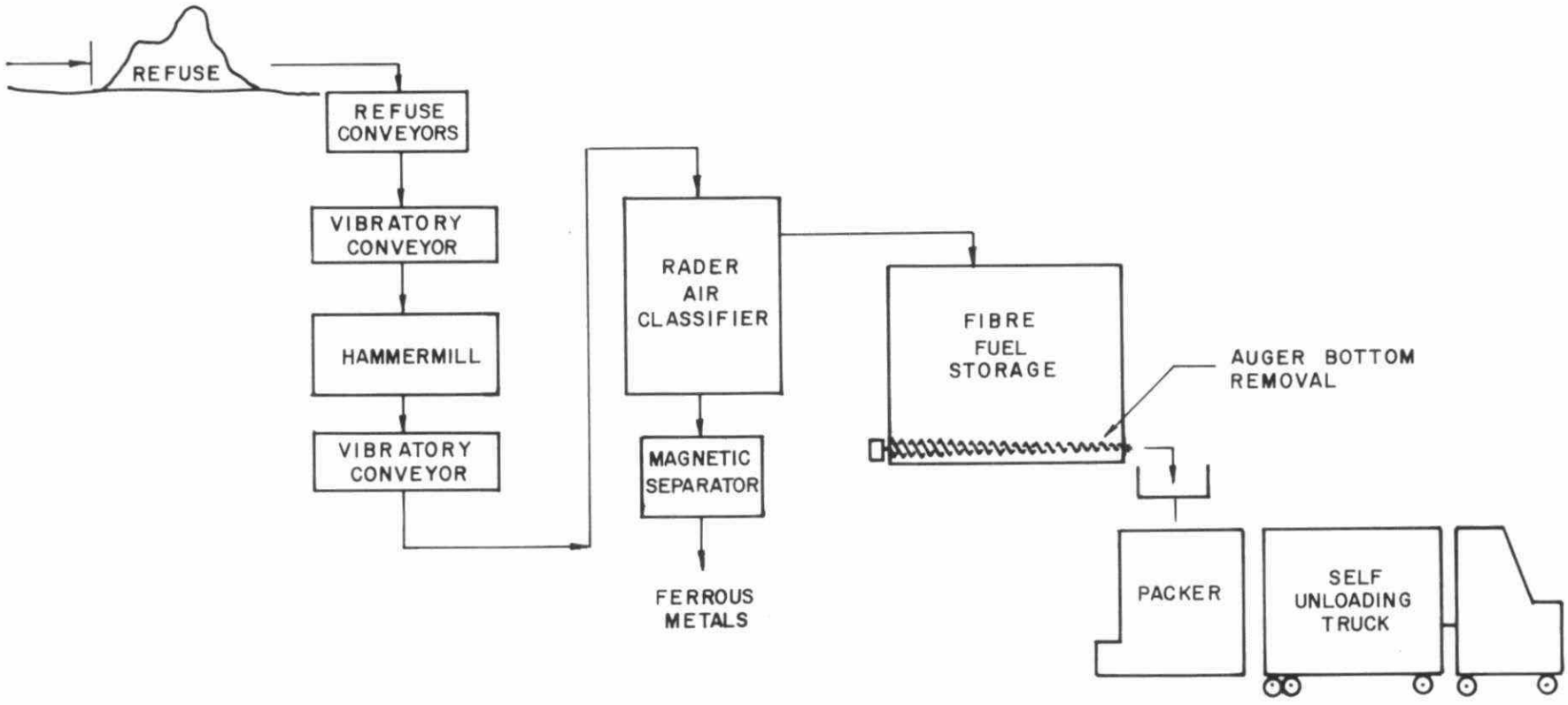
At the present nominal 300 ton per day firing rate, one 25 ton load of supplementary fibre fuel is delivered to the power plant every two hours.

At the Receiving and Firing facility (Meramec Generating Plant) the transport trailers discharge the fibre fuel to a receiving bin. This bin also has a traversing floor auger which delivers the material to a pneumatic feeder for transfer to a surge bin. The surge bin is equipped with four drag chain unloading conveyors, each of which feeds a pneumatic feeder. These four pneumatic feeders convey the supplementary fuel through separate pipelines directly to a firing port in each corner of the boiler furnace.

The Union Electric Meramec plant is presently using one of two twin boilers for test firing of the fibre fuel. The boilers are a Combustion Engineering design having a nominal rating of 125 megawatts each and burning about 56.5 tons of bituminous coal per hour at rated load.

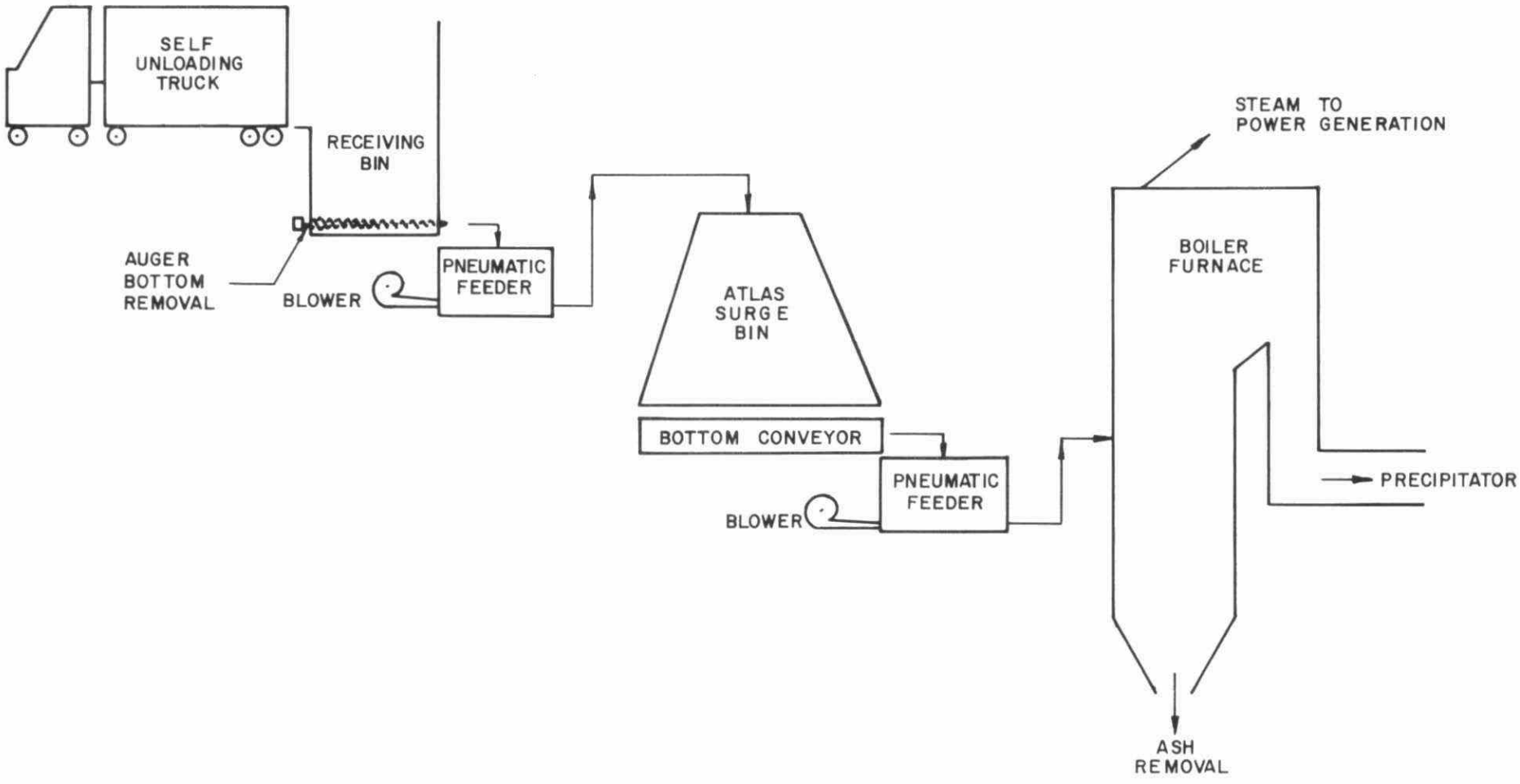
The unit is tangentially fired with four pulverized coal burners, one in each corner of the furnace. It is also fitted to burn natural gas. At full load the quantity of refuse equivalent in heating value to 10% of the coal would be about 12.5 tons per hour or 300 tons per 24-hour day.

The project is operating continuously and evaluation is being carried out.



HORNER & SHIFRIN FUEL RECOVERY PLANT - ST. LOUIS

16.2.1.7.



UNION ELECTRIC - FIBRE FUEL POWER PLANT - ST. LOUIS

16.2.1.7.

16.2.1.8 Garrett Research and Development Co.
1855 Carrion Road,
Laverne, California. 91750

Following extensive research into methods of producing synthetic fuels, the Garrett Company has developed a recovery system designed to produce heating gas or oil, plus glass and magnetic metals from municipal waste.

Incoming solid wastes are shredded and dried in a conventional manner and then passed through an air classifier which separates most of the metals, glass, and other inorganic materials. The overhead stream from the air classifier is subjected to a two-stage screening to improve separation of the inorganics. The remaining material is shredded a second time and then flash pyrolized where it is broken down into smaller molecules through the application of heat in the absence of oxygen. Oil, gas and char are recovered.

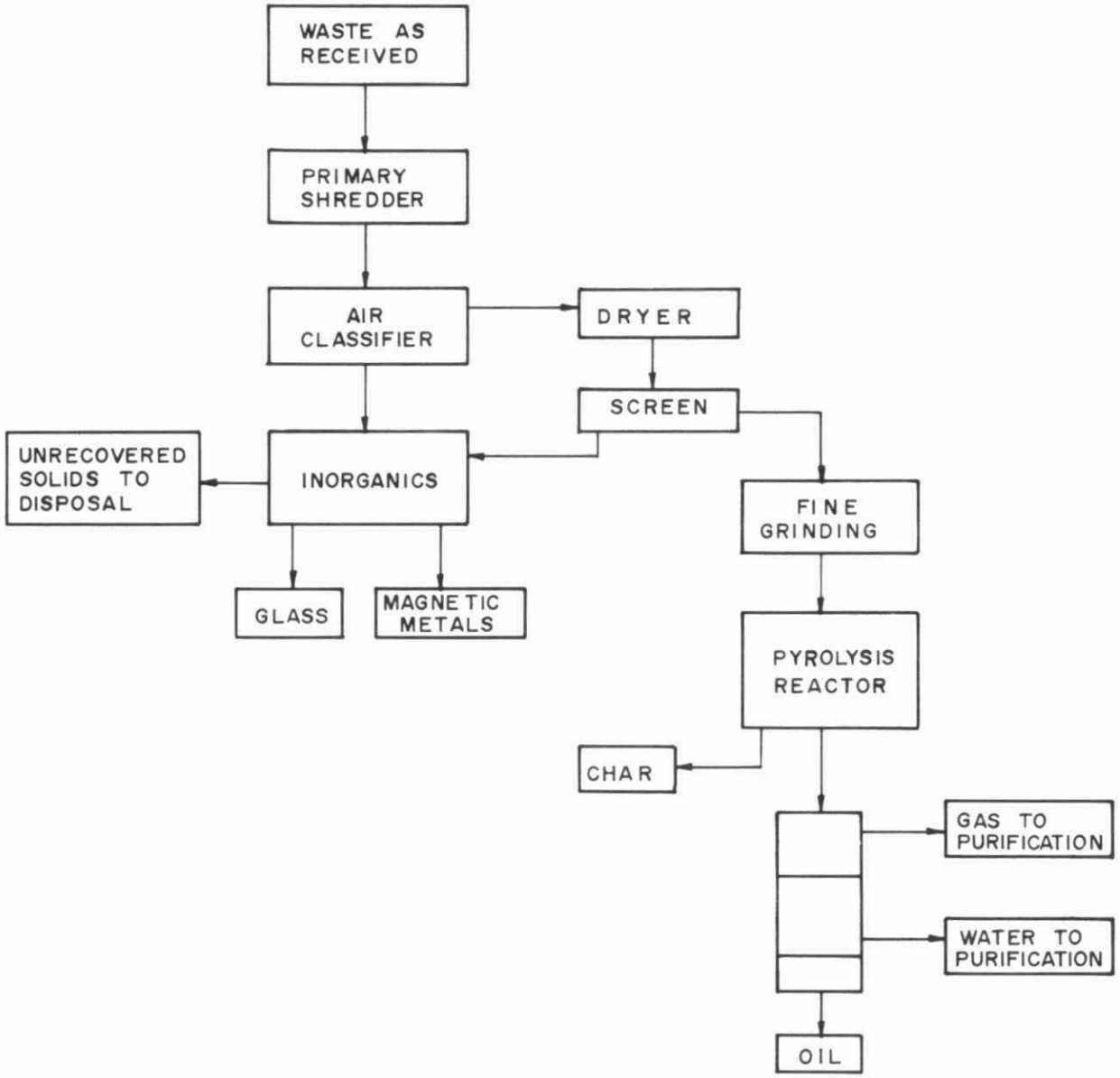
The Garrett process may maximize either liquid fuel yields or gas yields with Garrett claiming liquifaction as a more efficient process.

The heating value of this synthetic fuel oil is perhaps the most significant recovered resource, having a calorific value of about 75% that of No. 6 fuel oil by volume. It is claimed that about one barrel of oil can be produced from one ton of solid

16.2.1.8 (Cont'd)

waste in the liquifaction module, or about 6000 scf of gas with a heating value near 800 BTU/cu ft can be produced in a gasification module. To obtain yields this high, however, the feed to the reactor must be pure, dry, and of a consistent size, requiring a comprehensive preparation stage.

A 4 ton/day pilot plant has been in operation since 1972 and 1·200 T/D demonstration plant is planned. Engineering is approximately 1/3 complete with start of construction scheduled for September, 1974. In the meantime, Garrett is looking for a commercial application for their separation system and their glass and metal beneficiation processes.



GARRETT PYROLYSIS PROCESS

16.2.1.8

16.2.2 Material Recovery Processes

Known technology.

Included in this category are known wet and dry separation processes for recovering pulp, ferrous and non-ferrous metals, glass and plastics.

The processes include those of:

Black Clawson
Forest Products Laboratory
U.S. Bureau of Mines
Metropolitan Waste Conversion
Mitsubishi Petrochemical

See Drawing No. 982-130-8.

TABLE 16.2.2

SUMMARY OF RESOURCE RECOVERY PROCESSES

Materials Recovery Processes - Known Technology

Name and Location	Principal Product	Other Products	Capacity (Tons/Day)	Capital Cost ($/Ton/Day)	Operating Cost ($/Ton)	Revenue ($/Ton)	Net Costs ($/Ton)	Preliminary Separation Required Wet or Dry	Development Status
1. Black Clawson Middleton, Ohio	Pulp	Ferrous Metals Glass	500 (Estimated)	13,300	12.67	4.63	8.04	WET	50 T/D demonstration plant in operation since June, 1971.
2. Forest Products Lab. Madison, Wisconsin	Pulp	Ferrous Metals Non-Ferrous Metals Glass Steam	500 (Estimated)	38,800	27.80	20.18	7.62	WET	20 T/D pilot plant in operation.
3. U.S. Bureau of Mines Incinerator Recovery	Ferrous Metals Aluminum Zinc Copper	Glass	1,000	2,000	1.83	15.76	-13.93	DRY	4 T/D pilot plant operates in College Park - 250 T/D demonstration plant proposed.
4. Metropolitan Waste Conversion Houston, Texas	Ferrous Metals	Cardboard Compost	500	6,000				DRY	500 T/D commercial plant in operation since 1966.
5. Mitsubishi Reverzer	Plastics PE, PP, PS, ABS, PVC, etc.		4		N/A			DRY	20 systems presently in operation.

16.2.2.1 Black Clawson Fiberclaim Inc.
200 Park Avenue,
New York, N.Y. 10017.

Incoming waste except for large bulky items is conveyed into a Hydrapulper wet pulping machine which converts it into a water slurry with a 3½% solids content. The slurry containing paper, food waste, plastics, as well as glass, aluminum, metal, etc., is extracted from the bottom of the pulper through 3/4 inch diameter openings for processing.

Large objects such as stones, metal, cans, etc., are ejected near the bottom of the pulper and removed through a junker where they are washed in a drum washer and the ferrous metals removed by magnetic separation. The slurry from the pulper is pumped through a Liquid Cyclone to remove most of the inorganic matter. This is a low energy centrifugal separator operating at a 15 psi pressure drop. Particles removed, range in size from 3/4 inch to fine sand. The rejects from the cyclone are elutriated with recycled water to remove the bulk of any organic materials that may have tended to drop out of the stream. The washed residue is a concentrate containing about 80% glass and free aluminum. This concentrate is prepared for further separation and recycling. The

16.2.2.1 (Cont'd)

slurry now contains most of the paper plus other organics such as plastics, textiles, food waste and similar items. The next step is to reduce to fibre any paper that may have passed through the 3/4 inch extraction and to screen out all the stringy materials, plastic, twigs, leather, etc. This screening is done in a VR Classifiner which has a high speed rotor operating against a heavy screen plate with 1/8 inch diameter perforations. Defibering takes place by shearing and pulsating. A second stage of screening is performed in a conventional paper mill pressure screen, which has a cylindrical screen basket with 1/16 inch diameter perforations.

Objects larger than 1/16 inch are removed from the slurry in this operation.

The slurry is now subjected to a second stage of centrifugal cleaning through high efficiency cleaners to remove small slivers and fine dirt. The last step in mechanical separation is to remove the very short fibres and debris, food particles, clay fillers, etc., from the long cellulose fibre of papermaking quality. The slurry is pumped over an inclined screen with horizontal slots. About 85% of the water goes through the slots carrying the fine particles with it.

The long fibres pass over the surface of the screen and are recovered. The recovered fibre at about 3.5% solids is dewatered in two stages. The first stage to about 10% solids is accomplished in an inclined thickener. The 10% pulp discharges into a cone press where it is dewatered to approximately 40% solids.

The rejects from the various screens and cleaners are non-recoverable organic materials. These rejects are combined and pumped to a two-stage dewatering operation. The cake discharged from the final cone press is broken into crumbs and pneumatically fed to a fluid bed reactor for burning.

The fluid bed reactor is a 25 foot diameter Dorr-Oliver Fluo Solids reactor. Air from a 500 H.P. blower is blown into the windbox at about 4½ psi. The air flows up through a perforated plate into a bed of hot sand which is fluidized by the air. The organic residues are blown into the fluidized bed and burned at 1400^{o} to 1500^{o}F. The exhaust gases are cleaned of particulate matter in a venturi scrubber.

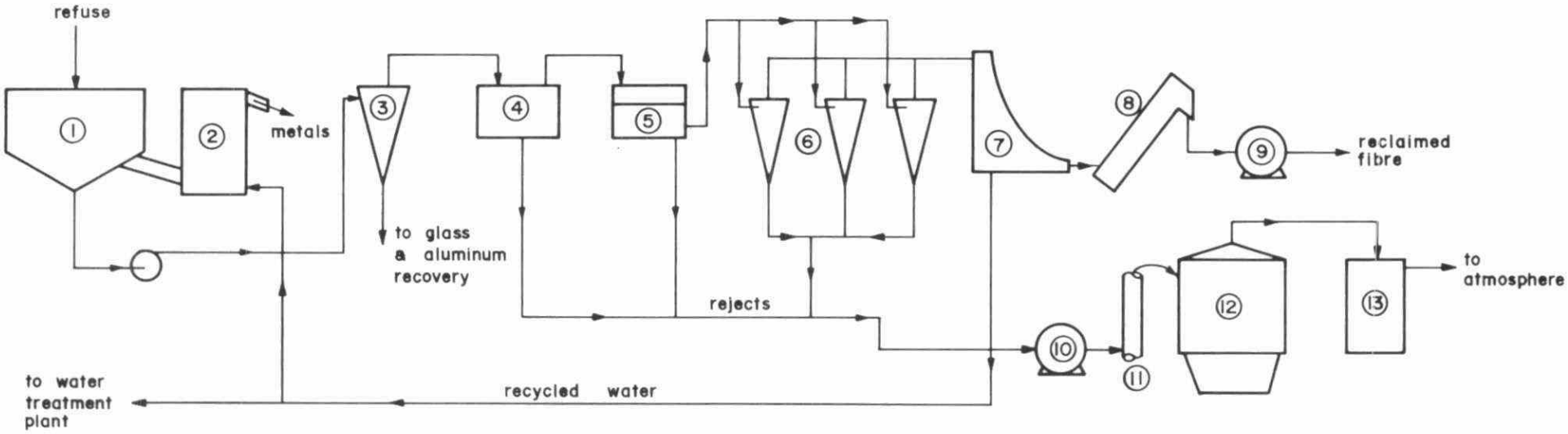
The heavy concentrated rejects from the cyclone are dried, screened, magnetically separated and

16.2.2.1 (Cont'd)

then air classified into light, medium and heavy fractions. The light fraction contains aluminum and heavier plastics. The heavy fraction contains the non-ferrous metals, and the middle fraction is glass which may be sorted by colour in a Sortex optical separator.

The Black Clawson demonstration plant at Franklin, Ohio, was built in conjunction with the town's new sanitary sewage treatment plant. The plant did not include the usual sludge digesting facilities. The sewage sludge from the water treatment plant is mixed with the non-recoverable organic residue from the waste treatment plant, dewatered and burned in the fluid bed reactor. The two plants are mutually dependent upon each other. The recovered products are pulp, ferrous metals and glass.

A 150 T/D (24 hr.) demonstration plant has been in operation in Franklin, Ohio, since 1971, and a 1000 T/D plant is proposed for Hempstead, N.Y.



① hydrapulper
② junker
③ liquid cyclone
④ classifiner
⑤ screen
⑥ centrifugal cleaners
⑦ fine screens
⑧ hydradenser
⑨ cone press
⑩ cone press
⑪ pneumatic feed
⑫ fluid bed reactor
⑬ scrubber & separator

BLACK – CLAWSON

SOLID WASTE PLANT

16. 2. 2. 1

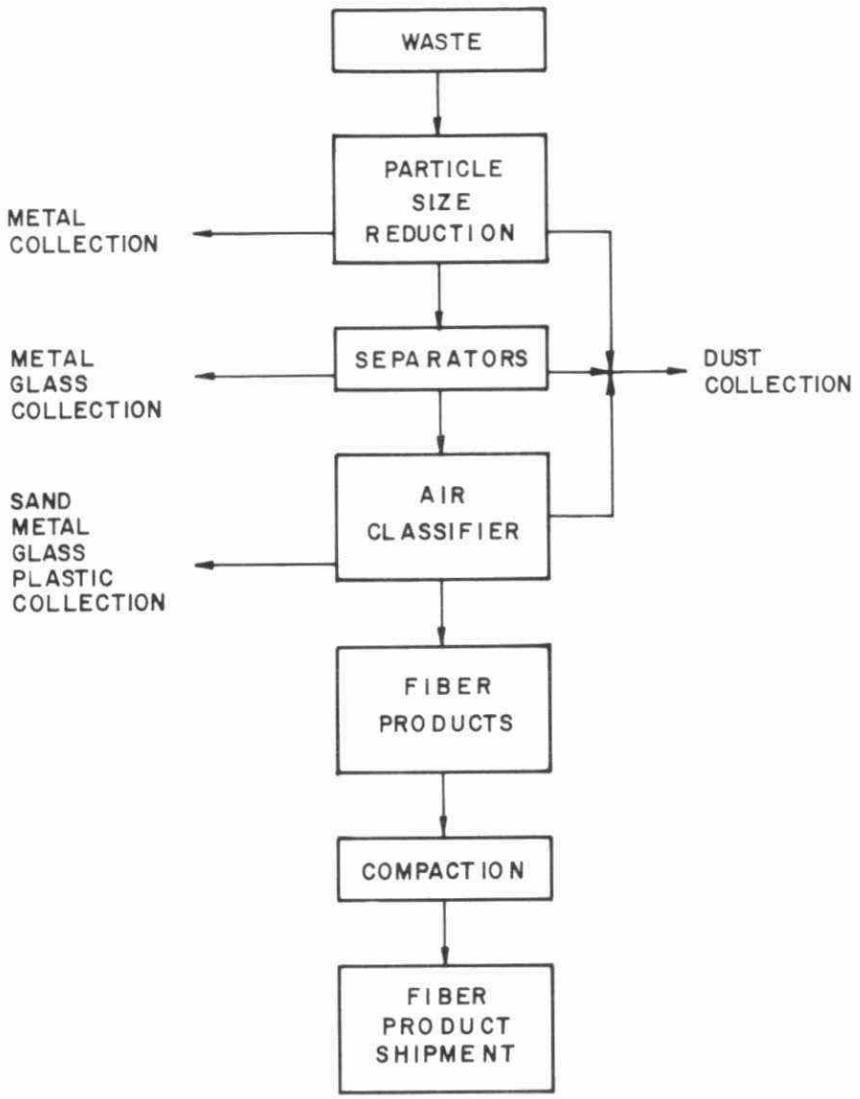
16.2.2.2 Forest Products Laboratory
U.S. Department of Agriculture
Madison, Wisconsin.

Laboratory testing and 20 T/D pilot plant have been operated with the object of recovering useable fibre, metals, glass and steam. Material was milled for particle size reduction, then sorted by means of an air classifier.

The paper fraction was processed for removal of foreign materials by dry screening. Forest Products Laboratory has placed emphasis on the paper fraction. This paper was being dissolved in a wet system as used by the secondary fibre industry for reclaiming fibre. The fibre was cleaned, de-inked, screened, and used for exploratory bleaching and paper machine operations.

The pilot plant is still in operation but has been used more for solving specific problems in waste paper reclamation rather than for the generation of data for full scale plant construction.

It is not known at this time if the plant will be utilized to develop data for later construction of a larger scale operation to reclaim pulp fibre from solid waste.



F. P. L. RECOVERY SYSTEM

16.2.2.2.

16.2.2.3 U.S. Bureau of Mines
College Park Metallurgy Research Center,
College Park, Maryland. 20740

Reclaim of metal and mineral fractions from incinerated municipal refuse.

This was a pilot plant operation brought on stream in November, 1969. The plant was assembled entirely of conventional minerals processing equipment, and used continuous screening, grinding, magnetic separation and gravity concentrating techniques to product metallic iron concentrates, non-ferrous metal concentrates, fine glass and fine carbonaceous ash tailings.

The first processing step consisted of screening the residue in a punched plate trommel drum having 1¼ inch diameter holes. During screening the residue was sprayed continuously with wash water. The oversize material scalped by the trommel, amounting to about 20% of the incineration residue, was discharged onto a packing belt conveyor, where material which could not be shredded by the hammermill was removed.

The minus 1¼ inch material from the trommel was washed and screened on a primary vibrating screen having 4 mesh and 20 mesh screen decks. The plus 4 mesh material was combined with the plus 1¼ inch material from the picking conveyor and was then

16.2.2.3 (Cont'd)

shredded in a hammermill. The minus 4 mesh material was combined with the shredded hammermill product. Following a series of vibrating conveyors and a bucket elevator, the product was discharged onto a secondary vibrating screen where it was again washed and screened on 4 mesh material and the minus 4 mesh plus 20 mesh material was then fed to drum type separators where iron was removed. The non-magnetic portion from the plus 4 mesh screen was fed to a vibrating screen having 3/4 inch openings where the massive non-ferrous metals were collected. The minus 3/4 inch material was combined with the minus 4 mesh, plus 20 mesh non-magnetic material. This combined product was then dewatered in a spiral classifier. The classifier removed fine organics as it conveyed glass and non-ferrous metals to a peripheral discharge rodmill. The glass was finely ground by the rodmill (sand grain size), and the non-ferrous metals being malleable were flattened. The separation of non-ferrous metals from the glass was made on a 20 mesh vibrating screen.

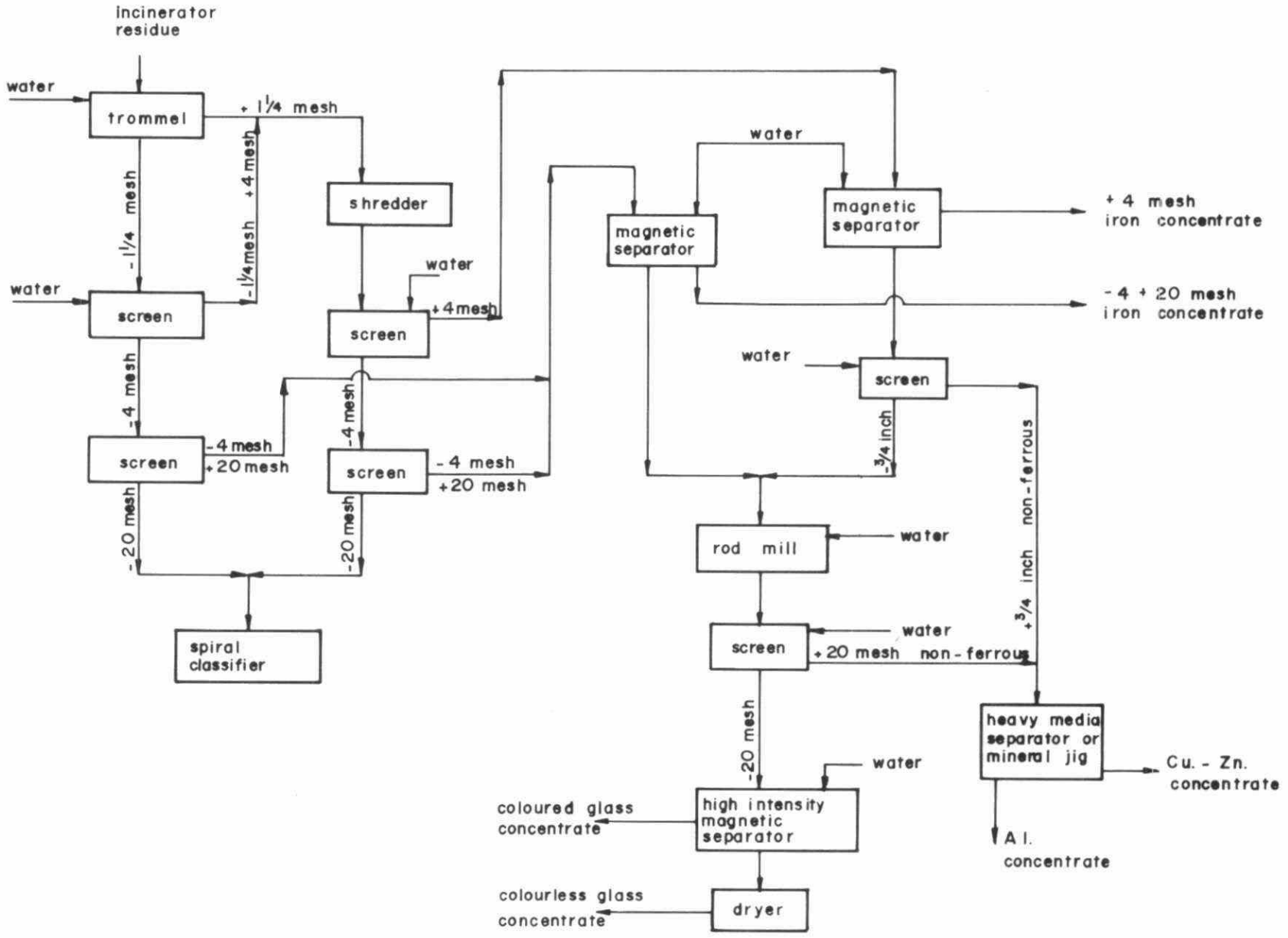
The mixed non-ferrous metal product was further beneficiated in a drum-type heavy media separator or a conventional mineral jig to separate the aluminum from the heavier non-ferrous metals.

The minus 20 mesh glass screened from the rodmill discharge was deslimed in a hydroclassifier wet magnetic separator. The glass was given a rough magnetic cleaning to remove highly magnetic particles, including some coloured glass.

A final magnetic cleaning of this rougher non-magnetic concentrate was made by a second high intensity wet magnetic separator, producing a final concentrate, essentially colourless flint glass. The flint glass concentrate was dewatered in a screen classifier and dried in a rotary drum dryer. The magnetic products from both separators were combined and dewatered in a screen classifier, and collected as a concentrate.

The minus 20 mesh material from the primary and secondary screening was classified as a waste sand product for disposal. All waste waters from the various classifying operations were combined and treated with flocculants in a thickener. The sediment was pumped to a drum-type vacuum filter to yield a filter cake for disposal. The water from vacuum filter and clarified thickener overflow was recycled.

Recovered materials consist of glass, aluminum, non-ferrous metals, ferrous metals.



U.S. BUREAU OF MINES - INCINERATOR RESIDUE PROCCESSING

16.2.2.3

16.2.2.4 Metropolitan Waste Conversion Corp. Houston, Texas.

The Metropolitan Waste Conversion system accepts unsorted municipal waste which is weighed on an incoming scale, dropped into a receiving hopper, conveyed to a shredder, screened, ferrous metals magnetically retrieved, cleaned and loaded into hopper cars.

The system, as initially installed separated organics from inorganics and composted them. The mechanical composter developed by Metropolitan Waste Conversion uses a plow-like device to expose all portions of the organics to aeration and to progressively move the material along a series of concrete troughs which allows considerable flexibility in retention time.

The 500 T/D plant (8 hrs.) built in 1966 has been operating under contract with the City of Houston since then except for a one-year shut-down.

The plant presently recovers corrugated cardboard, newsprint, and ferrous metals and is capable of producing compost or a light combustible fuel fraction.

16.2.2.5 Mitsubishi Petrochemical Japan

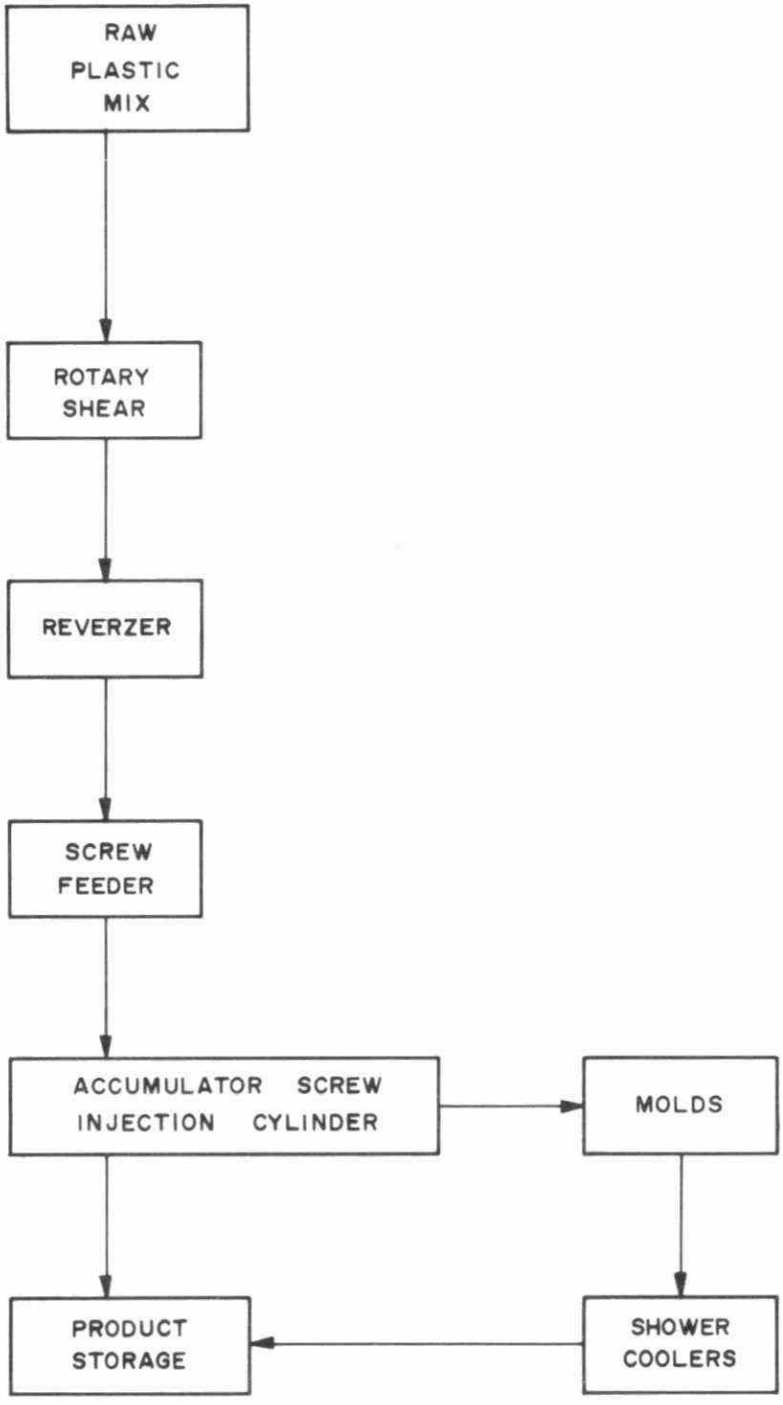
In Japan Mitsubishi Petrochemical has developed a machine known as the Reverzer, which is capable of mechanically re-working any misture of PE, PP, PS, ABS, PVC, Polyester and Nylon in molded film or fibre form.

The Reverzer will acdept up to 50% non-plastic, including sand, glass, cloth, paper, etc., depending on the end product. In practise, PS is maintained below the 20% level by weight if the end products require impact resistance.

There are presently twenty Reverzer units operating and another twenty to twenty-five to be installed in the coming year. The machines cost $130,000.00 each.

Each system is capable of utilizing up to 1100 lbs of scrap per hour, depending on the mix and accommodated molds up to 157 inches long, 59 inches wide, and 20 inches high.

Products presently being produced are fence posts and rails, gutters, cable spools, 2 x 2 and 2 x 4 lumber replacements. Molding costs run about 16¢ per pound.



MITSUBISHI REVERZER PROCESS FOR PLASTICS RECOVERY

16.2.2.5.

16.2.3 Composting Processes

Known Technology.

Composting of solid waste has not enjoyed universal success with a number of previously operated plants having shut down for economic reasons. The following is representative of successful operations:

Fairfield Hardy
Hercules Inc.
Buhler Process
Varro Process

See Drawing No. 982-130-8.

TABLE 16.2.3

SUMMARY OF RESOURCE RECOVERY PROCESSES

Composting Processes - Known Technology

Name and Location	Principal Product	Other Products	Capacity (Tons/Day)	Capital Cost ($/Ton/Day)	Operating Cost ($/Ton)	Revenue ($/Ton)	Net Costs ($/Ton)	Preliminary Separation Required Wet or Dry	Development Status
1. Fairfield Marion, Ohio	Compost	Ferrous Metals Non-Ferrous Metals Glass Paper	300	N/A				WET DRY	A 50 T/D pilot plant has been in Altoona, Penn. for nine years and a 300 %/D in San Juan, Peurto Rico.
2. Hercules Inc. Wilmington, Delaware	Humus Compost	Ferrous Metals Non-Ferrous Metals Glass Paper	500 plus 18 tons Sewage Sludge	24,000	12.40	8.67	3.73	DRY	System has been designed for the State of Delaware. System is combination of Fairfield Hardy and Pyrolysis.
3. Buhler Process	Compost		100	15,900	2.12	N/A		DRY	Plants in France, Germany, Spain, etc. Proposal to Metro Toronto in 1972.
4. Varro Process Brooklyn, N.Y.	Compost	Ferrous Metals	150	N/A				DRY	Plant in operation.

16.2.3.1 Fairfield Engineering Co.
Marion, Ohio. 43302

Fairfield Hardy Compost Plant

Description of Operation in Altoona, Pennsylvania. - 50 T/D.

Garbage is brought to the site by five ton packers and dumped on a concrete pad in front of the building. A front end loader is used to dump the garbage into a hopper as shown on the flow diagram.

The garbage starts arriving about 11:00 a.m. and consists of five or six truck loads. The garbage contains no tin cans or bottles and is not subject to any type of sorting at the plant, but is pre-sorted in the household.

Material is shredded in a dry grinder, the ferrous metals remaining are removed magnetically. The shredded residue is fed in cold at the outer periphery of the digester, and is immediately mixed with the hot and partially digested garbage.

The holding time in the digester is approximately seven days and the material is discharged through the centre.

No external source of heat is necessary to start digestion which is carried on at 155^{o}F and 50% moisture.

16.2.3.1 (Cont'd)

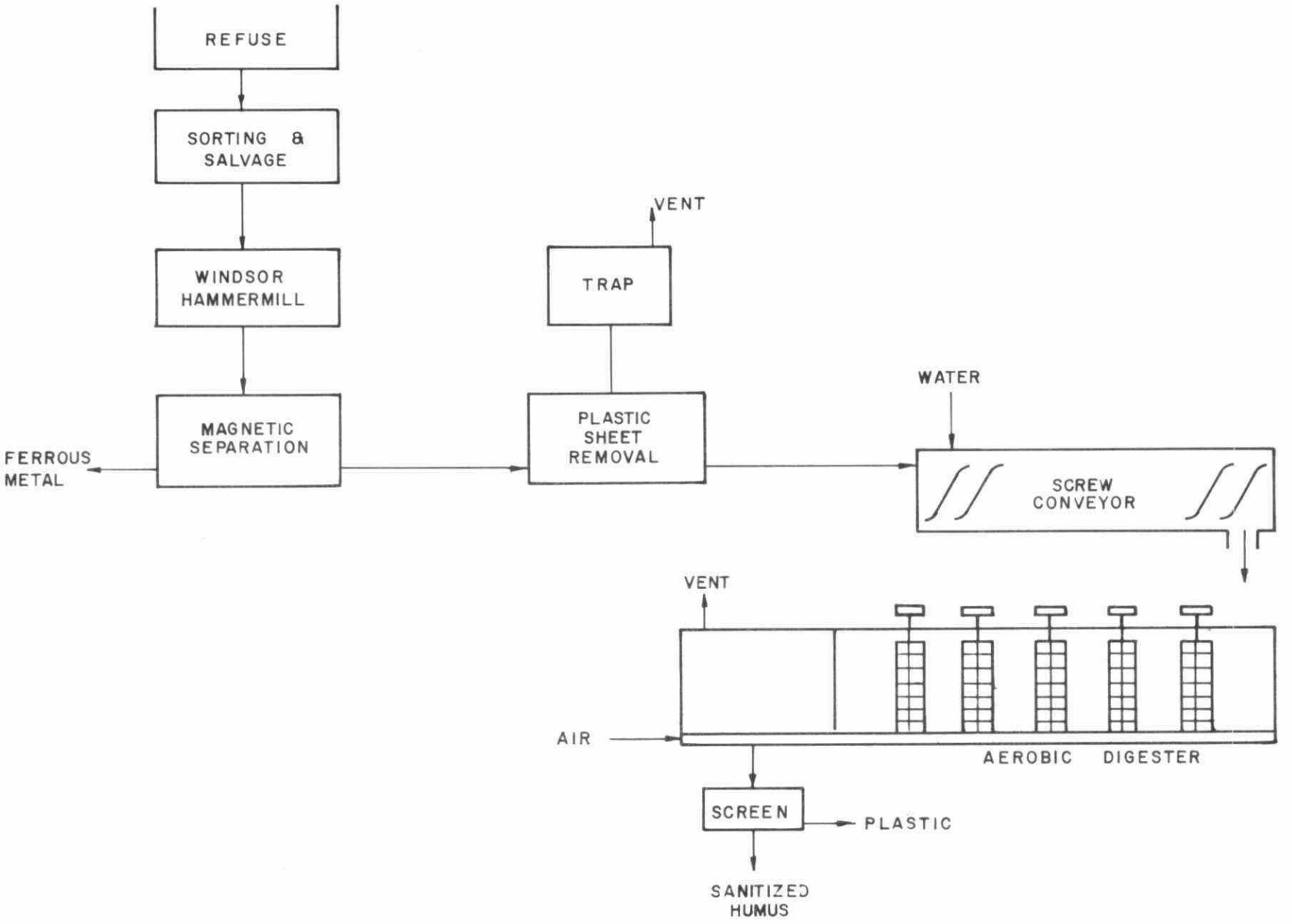
Oxidation for digestion is supplied by a fan delivering air into various points in the bottom of the digester. Control valves opened automatically by a lowering of the oxygen content at the various sensing points, is the digestion control method used, and prevents the system from going anaerobic.

The augers and feed screws operate only while new garbage is fed into the system, but the fan operates continuously.

Discharge from the centre operates for only one shift a day, is screened to remove plastics with both products being dumped on the floor and later taken away by a front end loader to be pelletized, stored outside, or sold raw.

From tests run by Fairfield Engineering, it provides a product reduced in quantity by approximately 1/3 and is also free of pathogenic material.

It can also handle a mixture of raw sewage and solid waste or 100% sewage sludge. A 300 T/D plant was in operation in San Juan, Peurto Rico, which accepted both commercial and domestic waste, none of which was pre-sorted.



FAIRFIELD HARDY - COMPOST PROCESS - ALTOONA PENN. 16.2.3.1.

16.2.3.2 Hercules Incorporated
910 Market Street,
Wilmington, Delaware.

Hercules Solid Waste Reclamation System

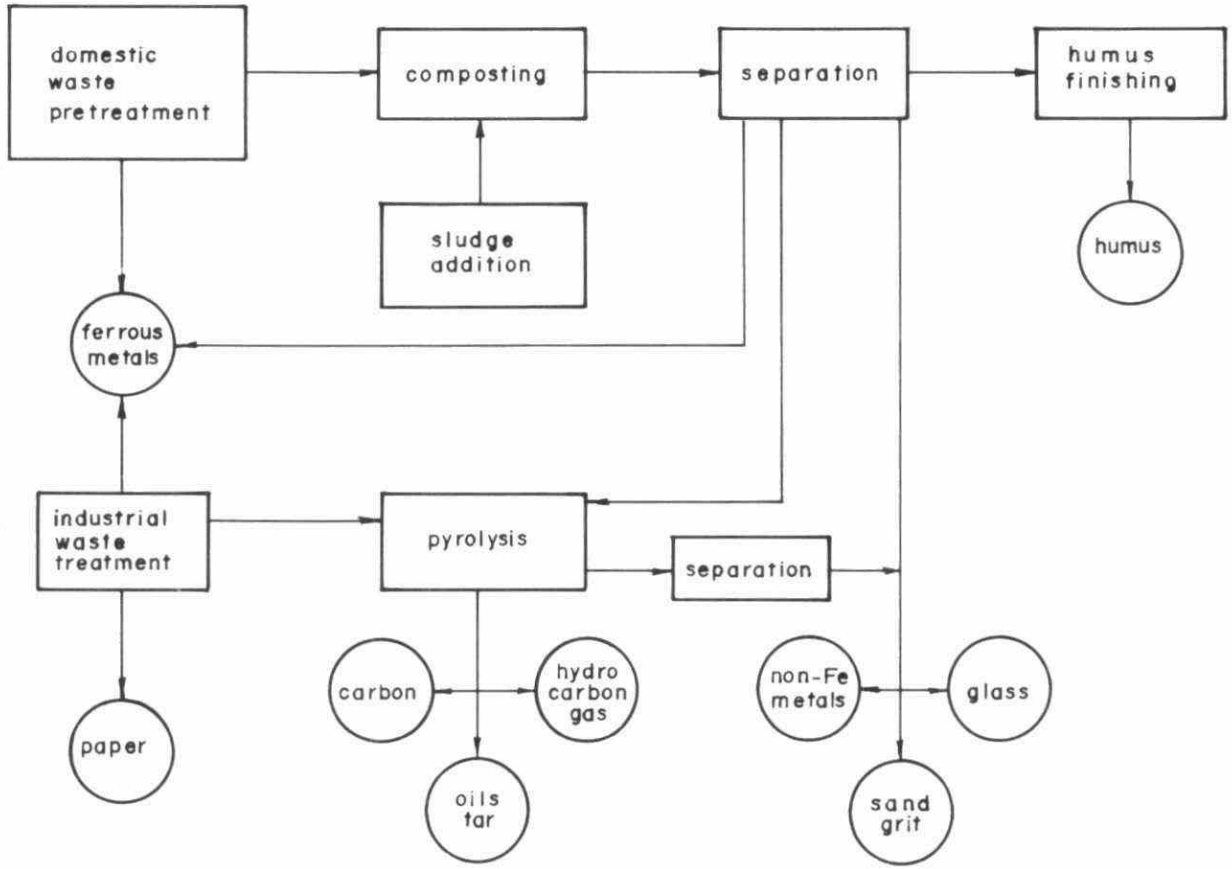
Hercules Incorporated has proposed a solid waste system consisting of a basic separation plant, a composting plant and a pyrolysis plant.

Domestic and commercial waste will be received separately at two different stations. Ferrous metals are to be removed before shredding and marketed.

Automobile tires, plastics and other materials are routed to the pyrolysis unit.

Balance is to be shredded, screened, etc., leaving an inorganic residue of glass, grit, sand and non-ferrous metals. The inerts (sand, etc.) are to be landfilled, the non-ferrous metals sold. The organic fractions are to be mixed with 8% sewage sludge to a resulting 50% moisture content and composted in a Fairfield-Hardy aerobic digester.

A 500 T/D (8 hrs.) demonstration plant is proposed for the State of Delaware. The main recovered products are compost, ferrous metals, paper, non-ferrous metals, carbon, char, combustible gases.



HERCULES RECLAMATION PROCESS 16.2.3.2.

16.2.3.3 Buhler Composting Process
Agents John Garay and Associates
250 Merton Street,
Toronto, Ontario.

The Buhler refuse-composting process developed by Buhler Brothers Ltd. in Switzerland is in operation in various forms in over forty plants in other than North American Countries.

The process is most often used in conjunction with sewage sludge and forms a part of a disposal system with the amount and quality of the compost geared to the needs of the market.

The capacity of any plant is governed by the capacity of the drum digester and the necessity to keep the material continuously in the drum for up to 48 hours. Plants handling from 100 to 350 tons of raw refuse per eight-hour shift are, however, not uncommon. The process description is as follows. Raw refuse is tipped into the receiving pit. A grab crane deposits this refuse into a hopper feeding a slat conveyor which feeds a rotary hammermill for coarse grinding.

The material is size classified by a coarse grating before dropping onto a feeder for ferrous separation by a magnetic drum. The crushed refuse passes to the drum digester where the material remains for 36 - 48 hours. Liquid sewage sludge,

16.2.3.3 (Cont'd)

raw or digested, if available, may be added to the digester drum which acts as a mixer.

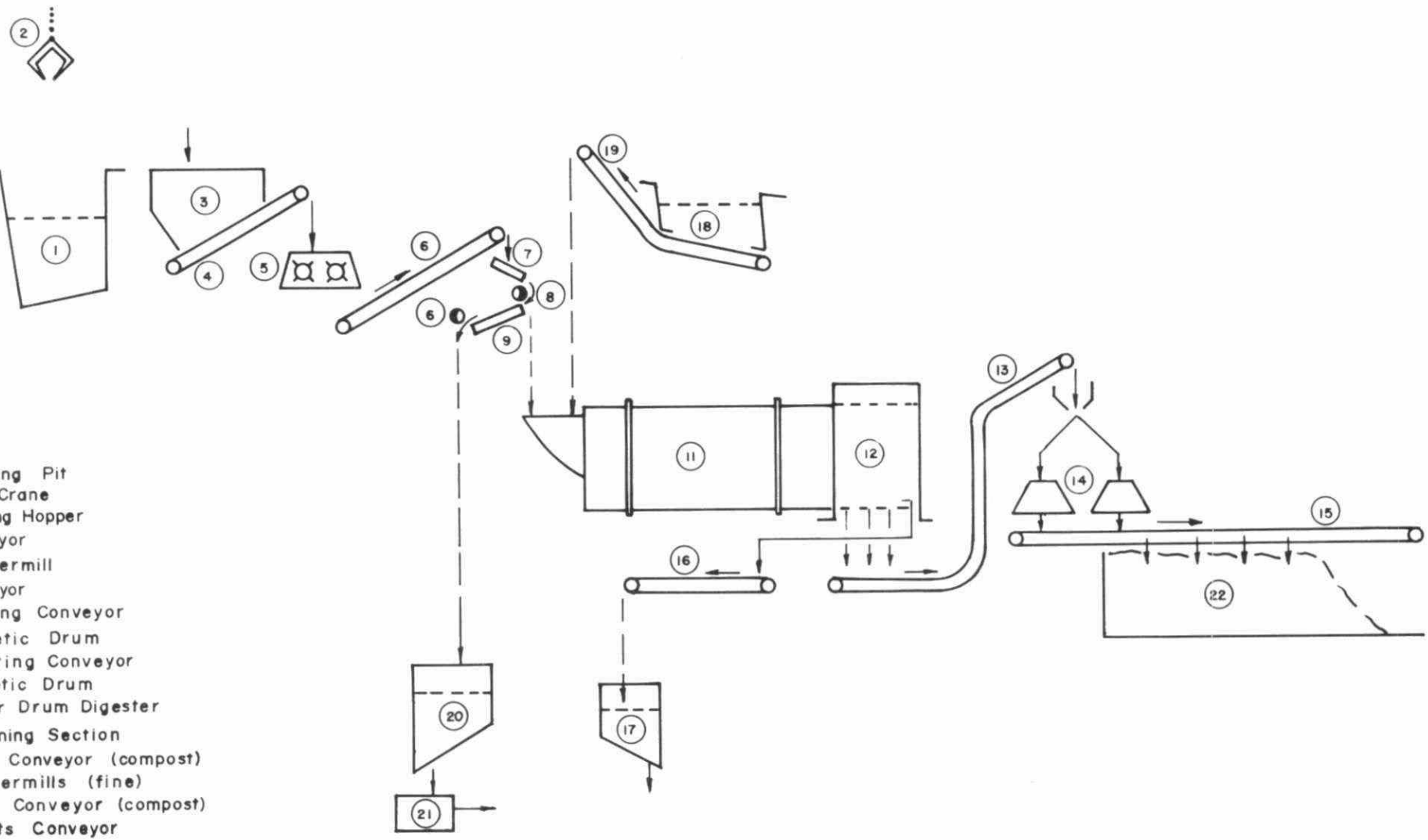
The material in the drum is kept at a temperature of 115° - 130°F with controlled aeration to ensure the product is hygienic and free of pathogenic germs. The outlet end of the drum has a rotary sieve from which three different materials are obtained.

(a) Rejects larger than 4 inches are removed to landfill or incineration.

(b) Material from 1 to 4 inches is fed back into the drum for further de-composition.

(c) The fine material smaller than 1 inch passes through a rotary fine mill where hard particles remaining are ground to sand grain size and are no longer noticeable in the final compost.

The prefermented product is then conveyed and set out in large windrows. At the end of a week the compost is turned over and set up in fresh smaller windrows for final maturation.



1. Receiving Pit
2. Grab Crane
3. Feeding Hopper
4. Conveyor
5. Hammermill
6. Conveyor
7. Vibrating Conveyor
8. Magnetic Drum
9. Vibrating Conveyor
10. Magnetic Drum
11. Buhler Drum Digester
12. Screening Section
13. Chain Conveyor (compost)
14. Hammermills (fine)
15. Chain Conveyor (compost)
16. Rejects Conveyor
17. Rejects Hopper
18. Dewatered Sludge
19. Sludge Conveyor
20. Scrap Iron Hopper
21. Metal Press
22. Compost Storage

BUHLER COMPOSTING PROCESS

16.2.3.3.

16.2.3.4 Ecology Inc.
221 Varick Avenue,
Brooklyn, N.Y. 11237

Varro Composting Process

Municipal refuse is trucked to holding pits and then conveyed to a primary shredder. Ferrous metals are removed magnetically, other inorganics remain in the final product. The refuse is shredded a second time before passing to the digester which is the key to the process.

The digester consists of eight stacked stationary platforms about 180 feet long and 12 feet wide. Refuse is moved from the top deck to each of the eight successively lower decks by variable speed harrows operating in alternating directions.

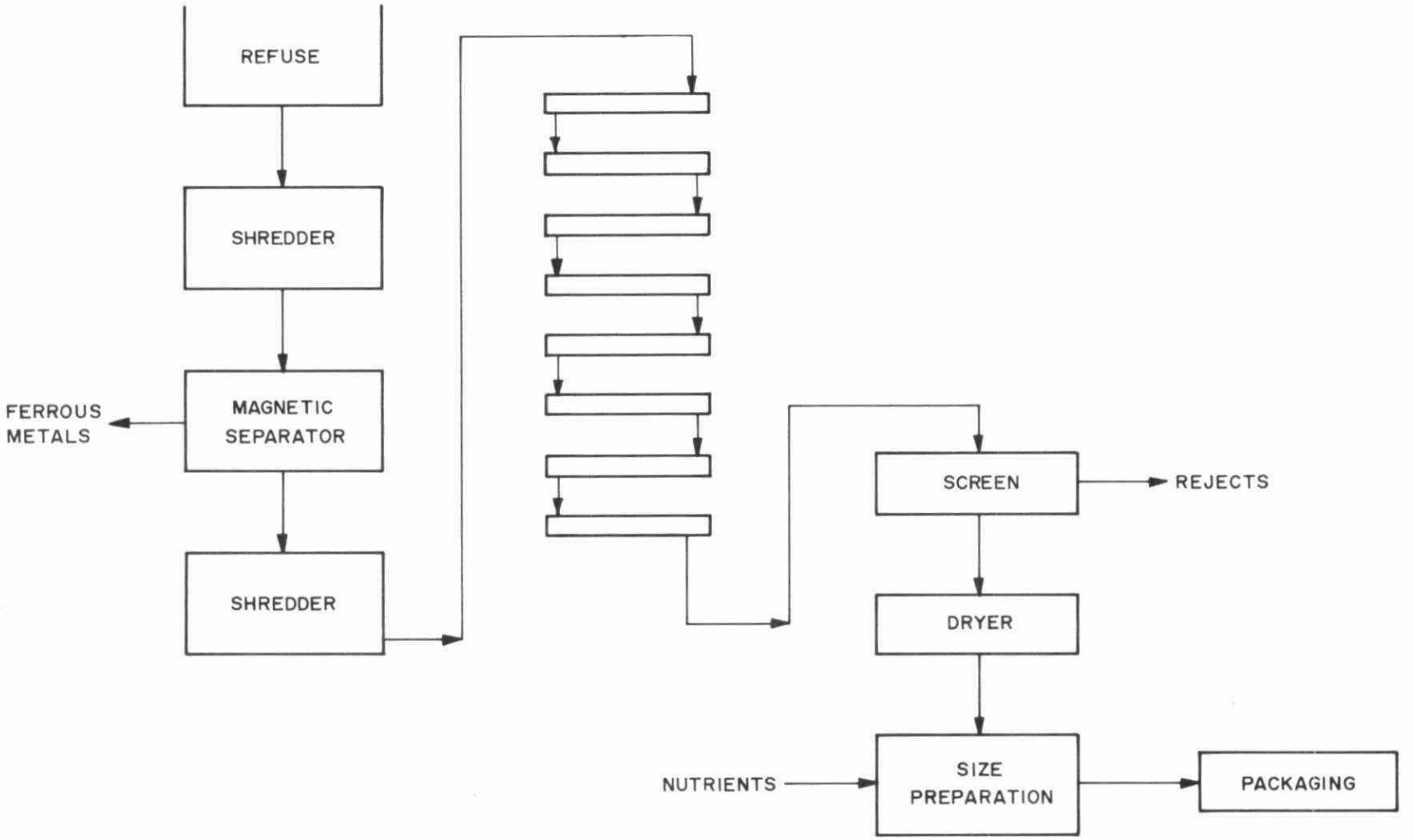
Liquid nutrients are added to encourage aerobic organisms. Aeration rate is controlled by plowing speed and depth of the refuse layer. Moisture in the form of hot water is added.

Temperature at each deck is controlled by electric air heaters.

It takes 48 - 60 hours for refuse to travel the ¼ mile along digester decks. At the discharge point rough compost is conveyed to screens which separate usable compost. The screened compost is

16.2.3.4 (Cont'd)

dried, fortified with nutrients and compacted. The finished product may be pelletized or granulated. The screen rejects are hauled to landfill.



VARRO COMPOSTING PROCESS

16.2.3.4

16.3.1 Energy Recovery

Developing Technology.

Included in this section are concepts for recovering energy in the form of fuel oil, electricity, gas or steam. These processes are generally in the laboratory or pilot plant stage with further development requiring a demonstration or operating plant.

Included are:

U.S. Bureau of Mines Hydrogenation
Combustion Power CPU - 400
Syngas Process
American Thermogen
Battelle Pacific

See Drawing No. 982-130-8.

TABLE 16.3.1

SUMMARY OF RESOURCE RECOVERY PROCESSES

Energy Recovery Processes - Developing Technology

Name and Location	Principal Product	Other Products	Capacity (Tons/Day)	Capital Cost ($/Ton/Day)	Operating Cost ($/Ton)	Revenue ($/Ton)	Net Costs ($/Ton)	Preliminary Separation Required Wet or Dry	Development Status
1. U.S. Bureau of Mines Hydrogenation	Oil (Fuel)	Ferrous Metals Non-Ferrous Metals Glass		N/A				DRY	Laboratory tests.
2. Combustion Power Menlo Park, California. CPU-400	Electricity	Ferrous Metals Non-Ferrous Metals Glass	1000 (Estimated)	9,300	7.36	5.77	1.59	DRY	80 T/D pilot plant late 1972, (severe wear problems as of December, 1973.)
3. Syngas Recycling Toronto, Ontario	Methane	Ferrous Metals Non-Ferrous Metals Glass		N/A				DRY	Laboratory tests. Patent has been granted - requires much more R & D plus piloting.
4. American Thermogen College Point, N.Y.	Steam	Frit	1650	10,300	6.42	3.01	3.41	NONE	Pilot plant proposed.
5. Battelle Pacific N.W. Lab.	Fuel Gas	Slag	200 (Proposed)	N/A					

16.3.1.1 U.S. Bureau of Mines
4800 Forbes Avenue,
Pittsburgh, Pennsylvania. 15213

Hydrogeneration process for recovery of oil products, from municipal waste.

Laboratory experimental research work has been conducted on a method of converting organic refuse into oil by treatment with carbon monoxide and water at elevated temperatures and pressures.

Using refuse from Altoona, Pennsylvania, which separates its organic garbage from inorganic hardware, a bench scale process was set up to handle about 1 lb per hour of waste slurry at pressures up to 5000 psig and temperatures near 500^{o}C.

The feed contained 5% sodium carbonate as catalyst. Carbon monoxide was pressurized, metered and admixed with the liquid feed in the reactor. Vigorous stirring up to 1000 RPM took place in the reactor to disperse carbon monoxide as fine bubbles. This kept the gas available for reaction and provided large gas-liquid interface area to facilitate mass transfer of the carbon monoxide into solution where it could react.

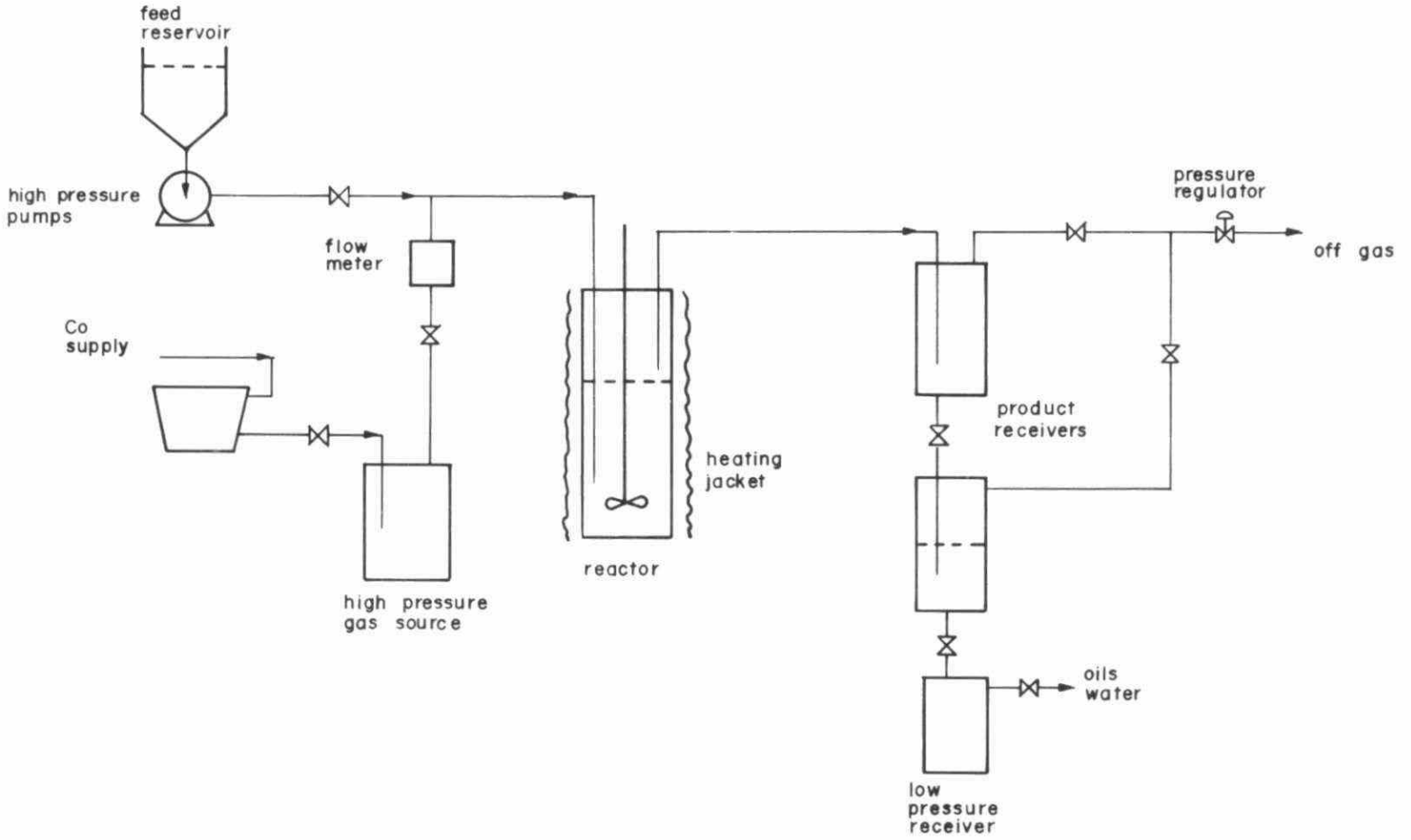
A gas liquid separation occurred in the top pressurized receiver while the whole liquid product drained into the lower pressurized receiver.

16.3.1.1 (Cont'd)

This whole liquid consisted of oil, water and unconverted solids. The oil absorbed in the solids is often a significant portion which may be further extracted with benzene.

Off gas from the receivers was let down through back pressure regulators that kept the whole system at the desired reaction pressures.

Work conducted on a laboratory scale only.



U.S. BUREAU OF MINES - HYDROGENERATION PROCESS
CONVERSION OF SOLID WASTE TO OIL PRODUCTS

16.3.1.1.

16.3.1.2 Combustion Power Company Inc.
1346 Willow Road,
Menlo Park, California. 94025

A pilot plant to handle 80 tons of refuse per day resulting in the generation of electricity from a gas driven turbine is in operation. It is known as the CPU-400 process.

The incoming packer trucks discharge the refuse into the receiving area where it passes directly into the shredders. The shredded material is immediately air classified with the high density metal and pulverized glass being recovered. The light materials, predominantly shredded paper and plastics are pneumatically conveyed to the shredded refuse storage.

Refuse leaving storage is conveyed to a rotary dryer where the heating value of the material is increased by tumble drying it in a stream of hot gas which comes from the turbine exhaust.

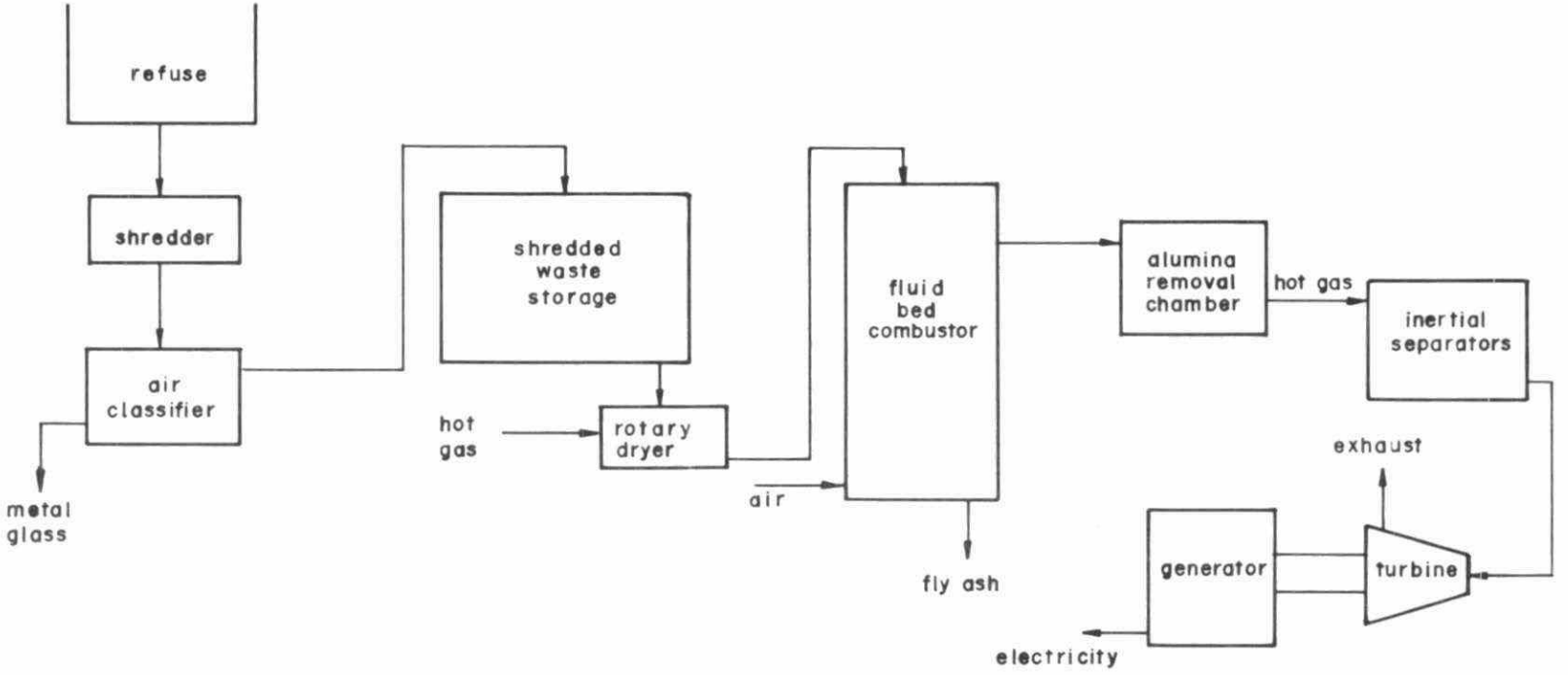
The shredded material is then fed to fluid bed combustors by high pressure feeders which meter the refuse at a rate suitable to control the gas turbine power output.

In the fluid bed, inert sand-sized particles are buoyed and mixed by an upward flow of air coming from a compressor. Combustion takes place at

16.3.1.2 (Cont'd)

temperatures between 1500^{o} - 1800^{o}F. The exhaust stream from the fluid bed is passed through an alumina removal chamber, then to inertial separators where particulate matter is removed prior to the gases flowing through the turbine.

It is necessary that the alumina removal system be effective in removing all aluminum oxides to offset high velocity impingement of particle deposits in the exhaust system.



COMBUSTION POWER COMPANY - CPU - 400

16.3.1.2.

16.3.1.3 Syngas Recycling Corporation
65 Queen Street West,
Toronto, Ontario.

The Syngas Process which is still in the early design development stage, is a patented concept involving the hydro-gasification of municipal and industrial wastes and/or sewage sludge, into a high BTU synthetic gas claimed to be interchangeable with natural gas.

Metals and glass would also be recovered and it is claimed "ore purer and more suitable for commercial use having no carbonization of metallics or melting of the glass". The end product which is an ash residue may have a place as a cement filler.

The patent description of the process is as follows: "Solid wastes are heated to 500°C - 675°C at 1000 - 3000 psig in the presence of gas containing at least 90 mole per cent hydrogen, to convert said wastes to a methane and ethane containing gas having no condensable oils and tars. The carbonaceous residue is also free of tars and oils".

The concept is based on work performed in the past with the gasification of coal. Coal gas, water gas, producer gas, were used as a wartime fuel source by both Germany and the U.K. and while the technology for producing such gases has been

16.3.1.3 (Cont'd)

established, these synthetic gases have been of a low BTU value. Syngas claim that after methanation their "product gas can have a heating value of at least 900 BTU per CF".

The user of the gaseous products from this process might be a Gas Utility Company because of its existing means of pipeline distribution. The concept does require further laboratory and pilot plant development work.

16.3.1.4 American Thermogen Inc.
112 - 20 14th Avenue,
College Point, N.Y. 11356

This concept makes use of a high temperature destructor to disposal of municipal and industrial waste recovering steam and a slag frit.

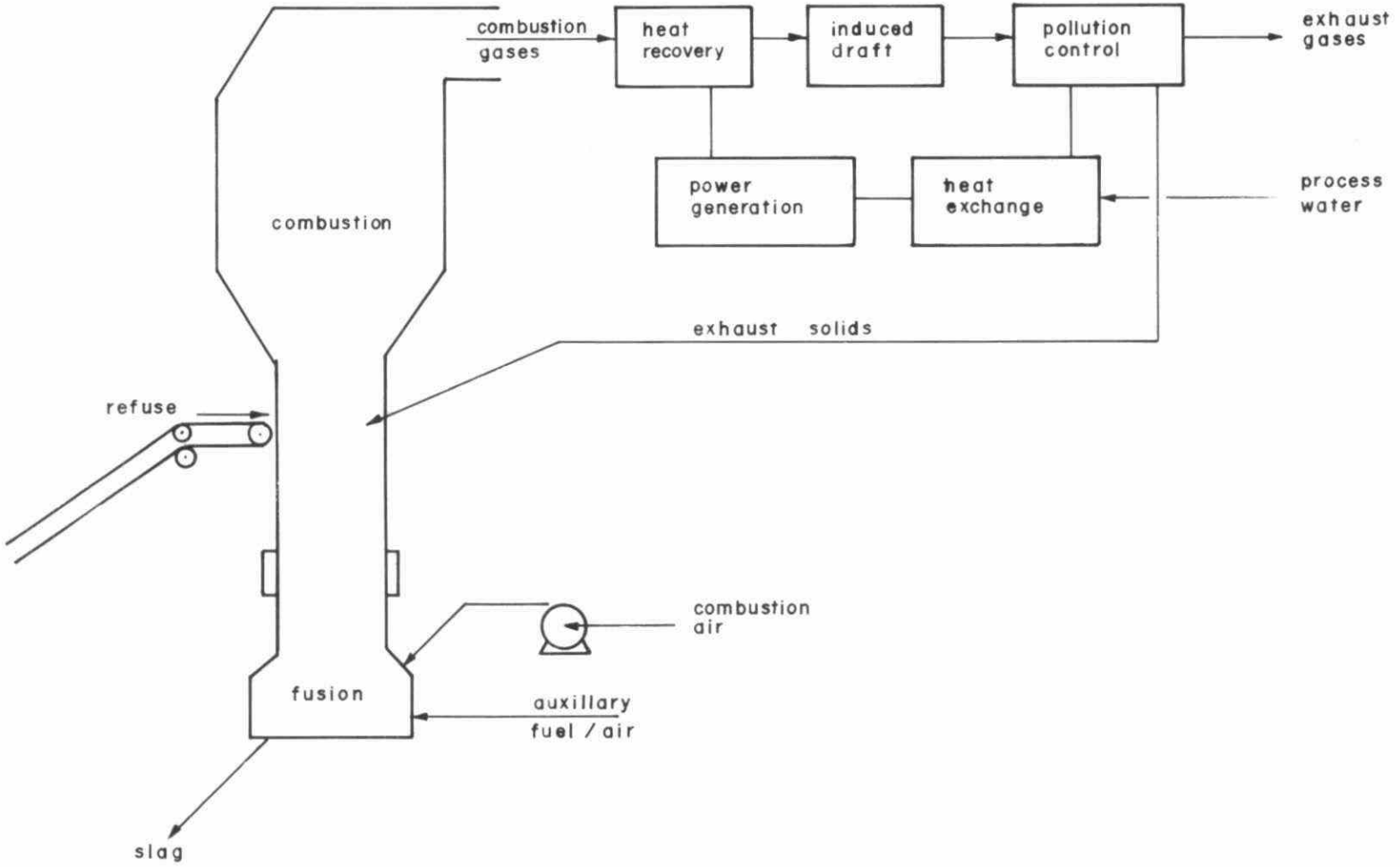
Waste as received is conveyed to the destructor where it undergoes complete burning, reducing it to 3% - 5% of the original volume. Burning takes place largely while the refuse is in suspension. Inorganics such as metals and glass are melted down at temperatures near 3000^{o}F. The unit requires the burning of a small amount of auxiliary fuel oil or gas. Molten materials are tapped from the bottom of the destructor into a water quench tank where they are shattered. A large portion of the refuse is

levitated as it enters the vessel by the stream of hot gases rising from the lower section. This refuse is burned with an insufficiency of air which is admitted tangentially in the upper expanded section of the vessel, resulting in some attendant pyrolysis of the organics. The flue gases containing some gaseous combustibles leaves the destructor through an overhead duct at temperatures near 1800^{o} - 2000^{o}F. Combustion is completed in a waste heat boiler generating steam.

Flue gases are water quenched prior to entering a wet scrubbing system where particulates are removed. The wet gases pass through a separator to remove water and are drawn into the induced draft fan and out the stack.

Scrubber water is recirculated and the solids content removed by filtering. The filter cake is returned to the fusion zone of the destructor.

Parts of the system have been tried in pilot plant studies. A proposal to build an operating plant is under consideration.



AMERICAN THERMOGEN HIGH TEMPERATURE INCINERATION

16.3.1.4.

16.3.1.5 Battelle Pacific Northwest Laboratories
Richland,
Washington. 99352

This is a pyrolysis-incineration process performed in a completely closed system. There is no release of fly ash fumes or smoke.

Refuse does not require presorting or shredding and is fed directly into a closed vertical reactor where it is progressively dried, charred and oxidized at relatively low temperatures. The refuse undergoes these transformations in a packed bed, settling under the force of gravity while reactant and combustion product gases rise countercurrent to the direction of solids movement.

The char is oxidized in the bottom of the reactor by a mixture of oxygen and steam. The hot reaction gases pass upwards to cause charring of the incoming refuse. The residual heat in the gases evaporate moisture and aid in drying the refuse entering the reactor. The final gases to leave the reactor contain hydrogen, oxides of carbon, water vapour and hydrocarbons.

These gases may be burned in a secondary burner or processed for recovery of organic compounds, further treated to produce heating gas. This off gas may be used to synthesize methane or produce electricity.

16.3.1.5 (Cont'd)

A 10 T/D pilot plant is in operation and 100 - 200 T/D demonstration plant is proposed.

16.3.2 Materials Recovery

Developing Technology.

Processes for material recovery from solid waste which are in the conceptual or pilot plant state, or which have not, as yet, been proven in North American practice. The next development for these processes would be a demonstration or operational plant. They include:

Strobel and Rongved - Fedway Process
Memphis State University - Wet Process
Alscope Consolidated
Grumman Ecosystems
Teledyne National System

See Drawing No. 982-130-8.

TABLE 16.3.2

SUMMARY OF RESOURCE RECOVERY PROCESSES

Materials Recovery Processes - Developing Technology

Name and Location	Principal Product	Other Products	Capacity (Tons/Day)	Capital Cost ($/Ton/Day)	Operating Cost ($/Ton)	Revenue ($/Ton)	Net Costs ($/Ton)	Preliminary Separation Required Wet or Dry	Development Status
1. Strobel and Rongved New York, N.Y. Fedway System	Cellulosic Material	Ferrous Metals Non-Ferrous Metals Glass Yeast	1500 (Estimated)	10,000	9.25	10.79	1.54 G	DRY	Some laboratory work done mostly at conceptual stage. Cost of Effluent Treatment not included.
2. Memphis State U Memphis, Tennessee	Fuel	Ferrous Metals Non-Ferrous Metals Fibre	3000 (Estimated)	5,000	3.00	4.15	1.15 G	DRY	Conceptual stage. Cost of Effluent Treatment not included.
3. Alscope Consol Vancouver, B.C.	Newsprint Fibre Pulp	Ferrous Metals Non-Ferrous Metals Glass	1000 (Estimated)	29,000	60.30	35,80	24.50 Cr.	WET or DRY	Some laboratory tests done, some engineering studies done.
4. Grumman Ecosystems "Selectomatic Commest"	Fibre	Ferrous Metals Non-Ferrous Metals Glass	1600 (Proposed)	10,000	10.97	15.41	4.44	DRY	Plants operating in Italy only. Plant proposed for Honolulu.
5. Teledyne Systems	Fuel	Ferrous Metals Non-Ferrous Metals Glass	Proposal					DRY	Proposed plant for North Baltimore County, Maryland.
6. University of Texas	Plastics PVC and PE		Laboratory Tests	N/A					Undergoing evaluation.

16.3.2.1 Strobel and Rongved
468 Park Avenue South,
New York, N.Y. 10016

The concept, known as the "Fedway" system, is based on laboratory scale tests with the objective being the recovery of cellulosic material, metals, glass and Torula yeast.

The process planned calls for the refuse to be reduced in size to about seven inches in a primary shredder, then reduced again to about two inches in a secondary shredder. The shredded material would then be screened and aerated and ferrous metals removed magnetically.

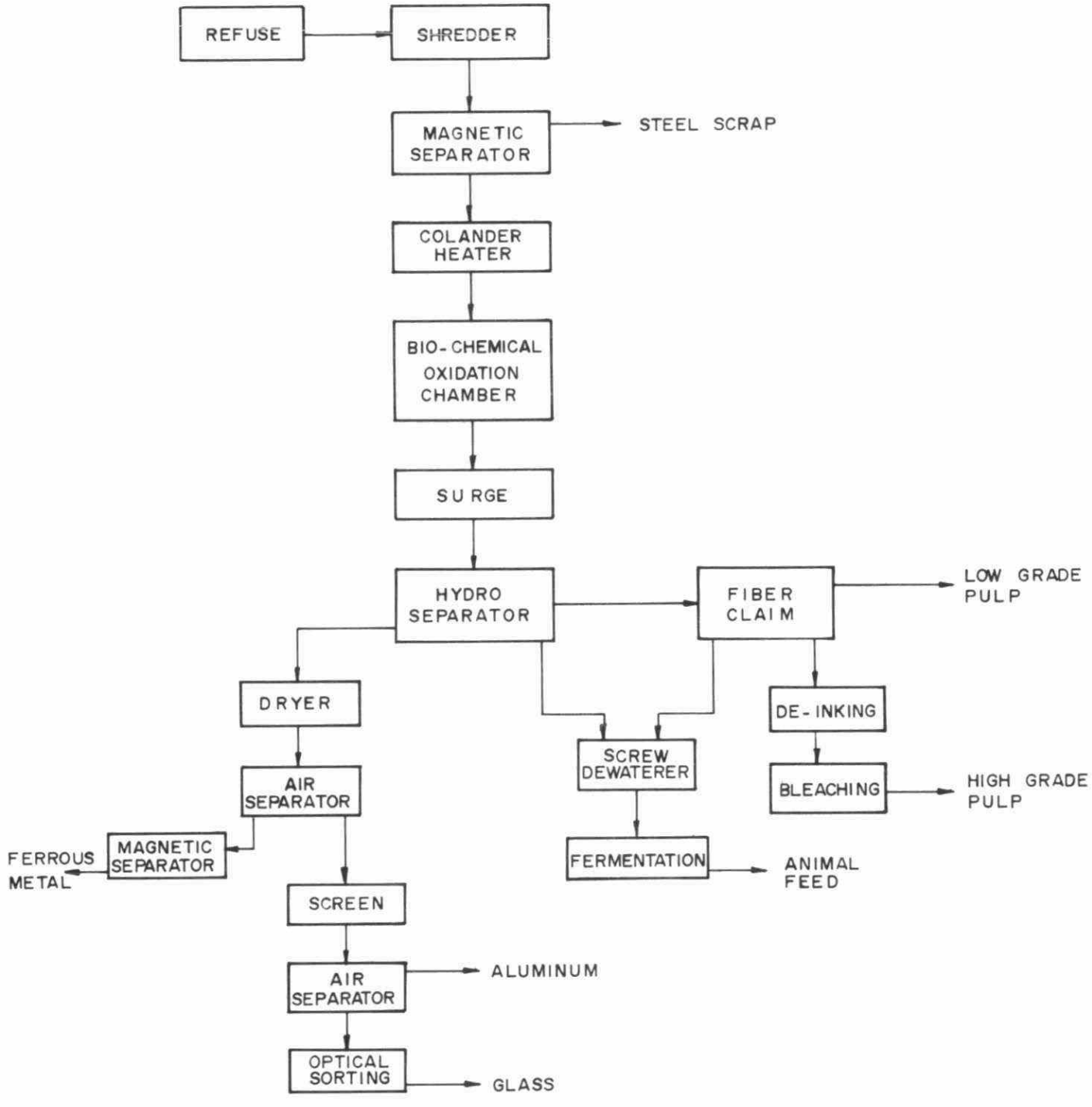
Shredded refuse is then moistened and heated in a colander heater to about 180^{o}F prior to going to a biochemical oxidation chamber where at a temperature near 150^{o}F it is maintained in an oxygen rich atmosphere with an 80% relative humidity.

The material is agitated and aerated in the chamber for 3 - 7 days. Fats and waxes are removed. The waste then passes to a hydroseparator which pulps the material. Heavy objects are ejected separately due to differences in specific gravity. The fibre may be processed for recycling. The remaining waste liquor is dewatered and fermented where yeast is produced for animal feed.

16.3.2.1 (Cont'd)

The recovery of the balance of light and heavy materials is largely conceptual with the suggested use of air separation and screening.

Some laboratory work has been done.



FEDWAY PROCESS

16.3.2.1.

16.3.2.2 Memphis State University
Engineering Research Institute,
Memphis, Tennessee. 38111

Memphis State University has reported a design concept for the recovery of fibre, ferrous metals, aluminum, glass and fuel.

Material would be wet shredded or hydrapulped. After removal of paper, glass and metals, the remaining material would be transported by sewer to a treatment plant.

The sludge from both sewage and solid waste would then be dried for use as a supplementary fuel in a power plant.

As this is still in the conceptual stage, no lay-out or equipment design information is available.

16.3.2.3 Alscope Consolidated Ltd.
Vancouver, B.C.

Alscope Solid Waste Pulp Recovery Process

A nitration process developed by Kilborn Engineering Ltd. for Alscope Consolidated Ltd., is used on the organic fraction of solid waste to digest vegetable and food waste, leaving a cellulose fibre residue, plastics and inerts.

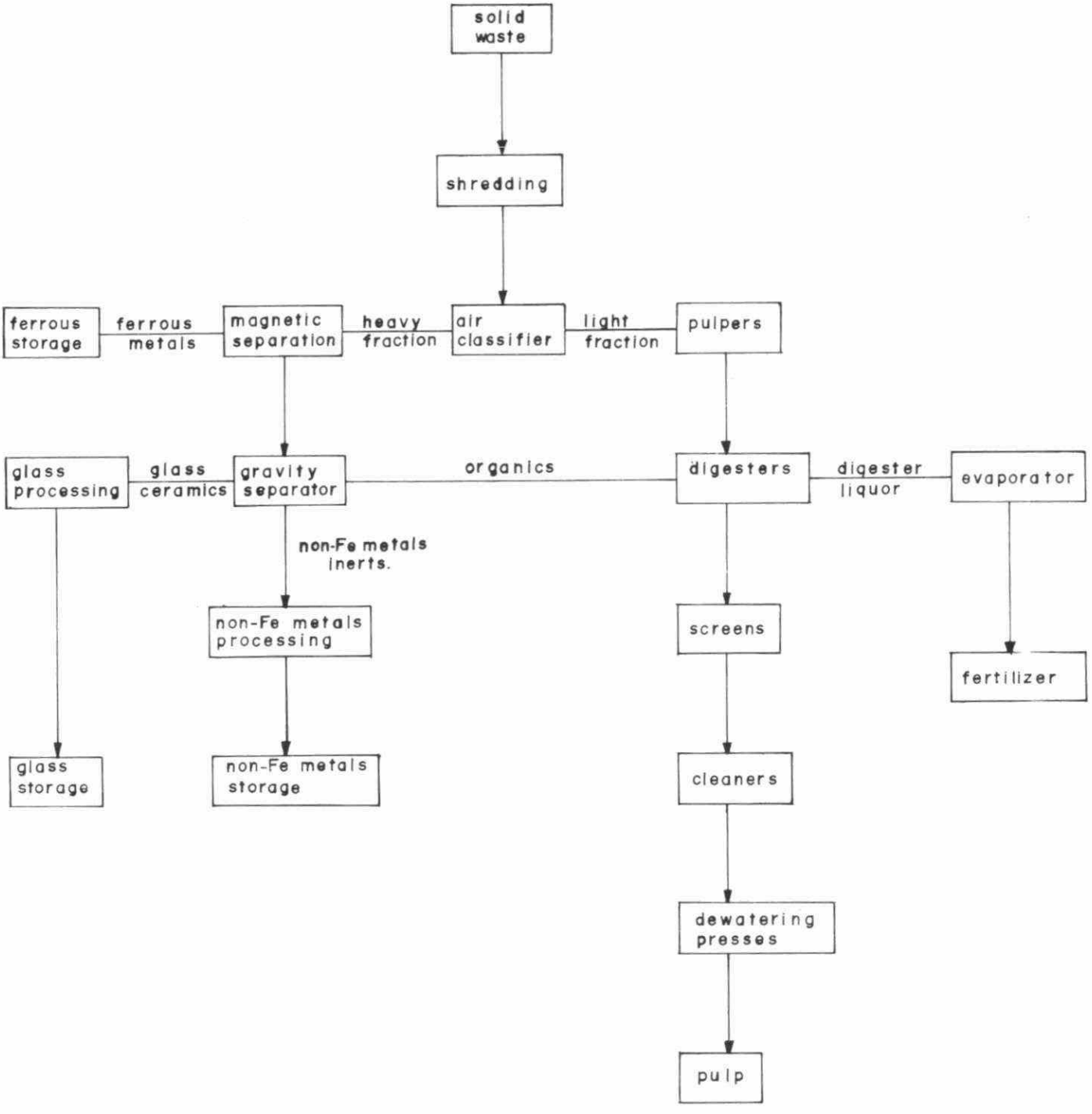
The plastic and inerts are removed by successive screening and centrifuging operations, leaving a a relatively clean pulp which at its present state

16.3.2.3 (Cont'd)

of development appears suitable for newsprint furnish.

The process is still in the laboratory stage but offers considerable possibility for reclaiming a high percentage of the cellulose fraction of solid waste.

The process does not contaminate the environment having only inerts and a nitrogen rich liquor residue having considerable fertilizer value. No incineration of residue is anticipated.



ALSCOPE SOLID WASTE PULP RECOVERY PROCESS

16.3.2.3.

16.3.2.4 Grumman Ecosystems Corporation
1111 Stewart Avenue,
Bethpage, N.Y. 11714

Grumman is the sales and construction representative for the "Selectomatic Commest" system designed in Italy by Alberto Cecchini.

The Cecchini organization claims two plants in operation, including a 1200 ton per day plant at Roma, Italy, a 200 ton per day plant at Perguia, Italy, and presently planning a 900 ton per day operation at Naples.

The Roma plant produces "usable paper pulp from waste paper, metal recovery for the scrap markets, and processes organic matter into saleable animal food pellets".

The principle of operation is described as follows.

"Material is dumped from pick-up vehicles into a holding bin to allow 24 hours operation. A crane operator removes bulky material for mechanical shredding prior to recycling.

Refuse is placed on conveyors equipped with cutting knives to open refuse bags. Material is tumbled to separate before entering vibratory air selection conveyors.

16.3.2.4 (Cont'd)

Paper and cardboard is pulled by air from the tumbled mass and goes to a pulper where chemical treatment produces a saleable pulp.

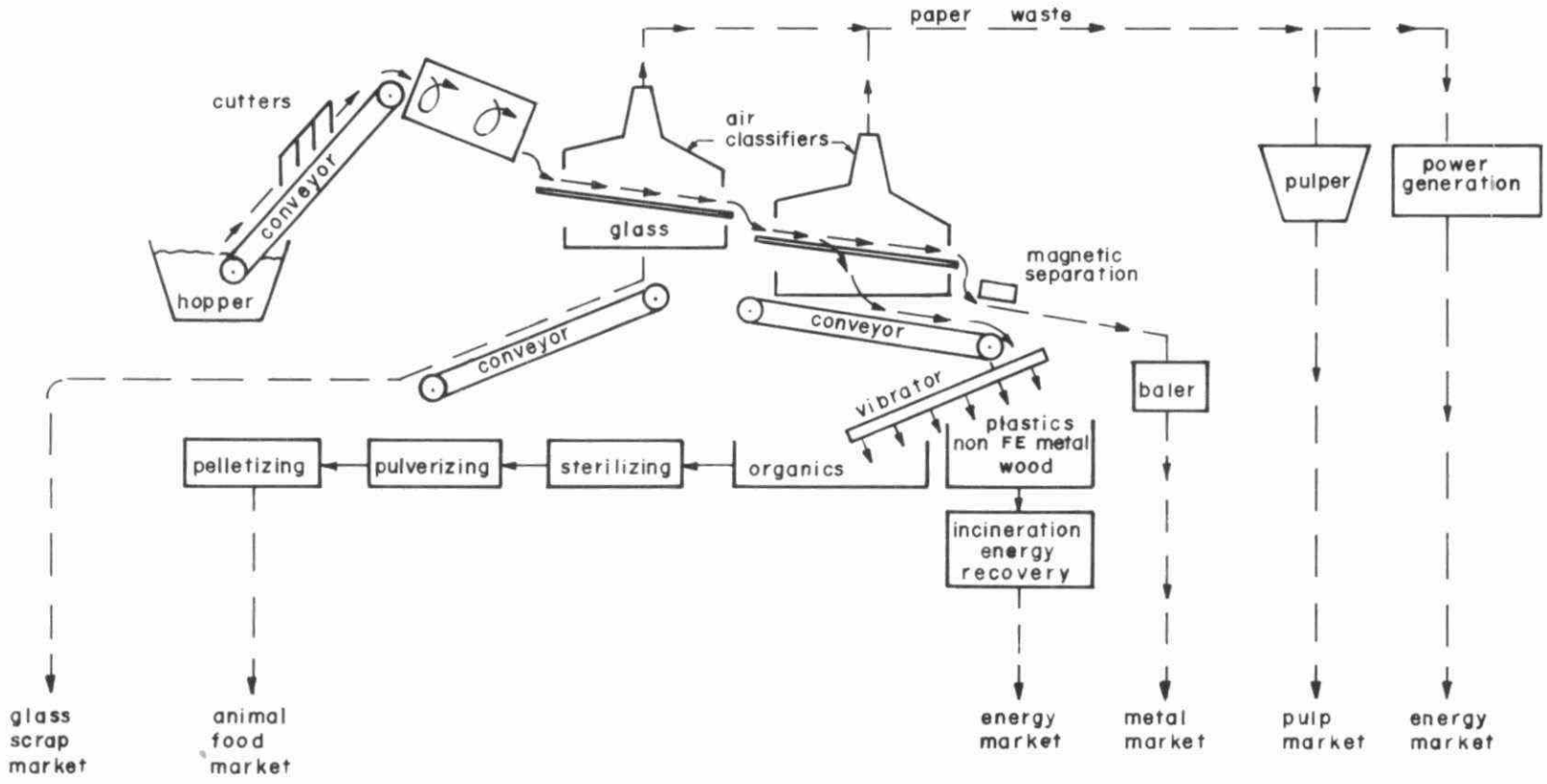
Ferrous and non-ferrous metal is separated by weight and magnetic equipment, cleaned, washed and baled.

Glass is separated by weight air classifiers and is pulverized. It may be colour sorted by sonic separators.

Organics are washed, sterilized, pasteurized and powdered then dried and extruded into animal fodder pellets.

Plastics, wood, etc., are incinerated for destruction. The waste heat produces steam for sterilization and cleaning".

Proposal to construct and operate a 1600 T/D plant for Honolulu is presently being reviewed.



GRUMMAN SELECT-O-MATIC COMMEST RECYCLING

16.3.2.4

16.3.2.5 Teledyne National Company
110 West Timonium Road,
Timonium, Maryland. 21093

This is a conceptual plan to design, construct and operate a Recovery Plant for North Baltimore County, Maryland.

It is visualized that mixed refuse would first enter; (a) the Receiving and Initial Storage Component which consists of automatic scales, storage pits, overhead crane system, and a heavy duty shredder for pre-processing bulk waste such as refrigerators.

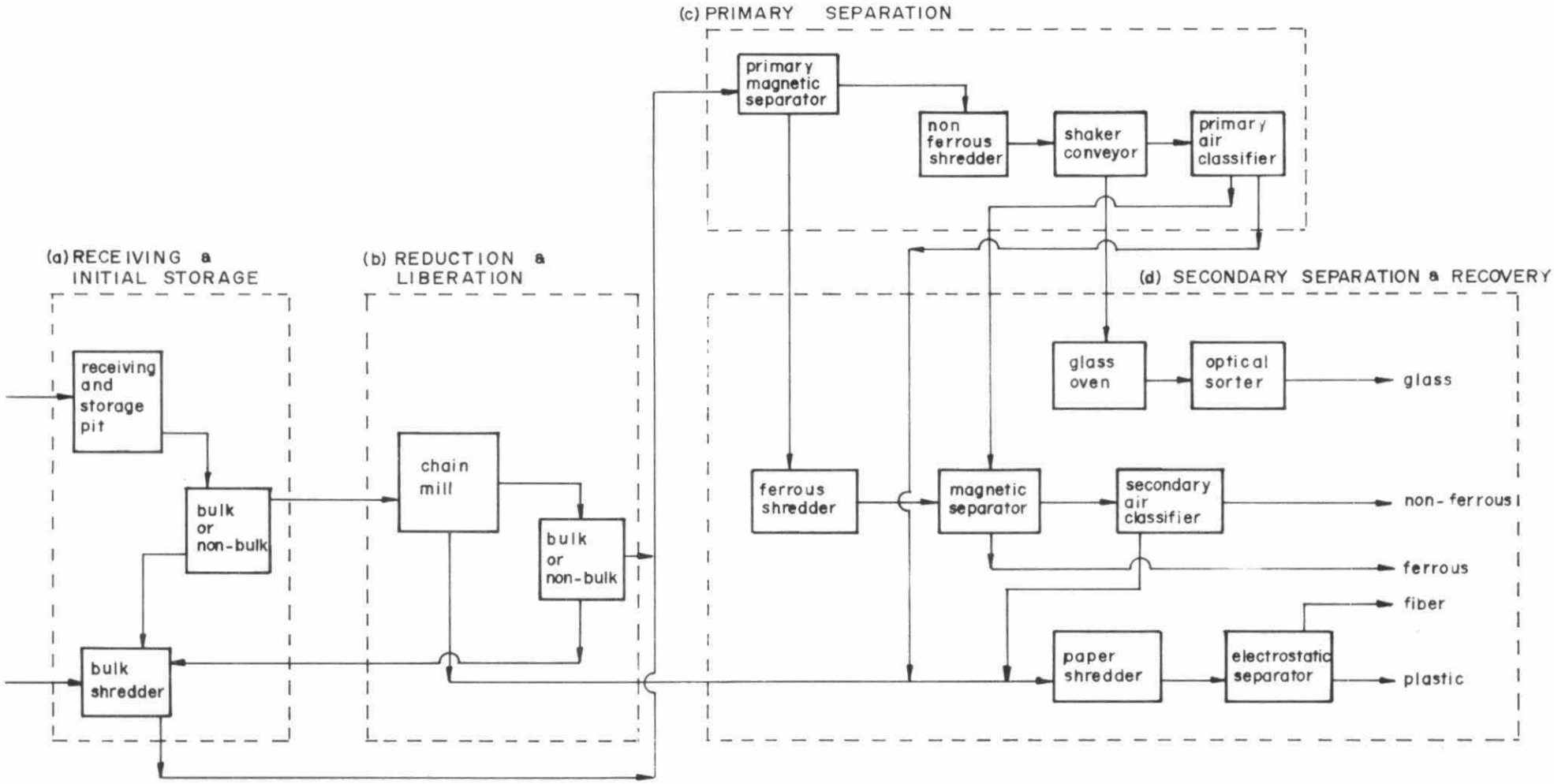
The refuse then would pass to; (b) the Reduction and Liberation Component where it is liberated from plastic bags and containers by means of a chain mill.

It would then pass to; (c) the Primary Separation Component which employs magnetic separation, non-ferrous shredding, shaker conveyors and air classification equipment. The separation process is a dry process.

The materials would then go to; (d) a Secondary Separation and Recovery Component where they undergo a secondary ferrous shredding and magnetic separation.

16.3.2.5 (Cont'd)

Materials from the primary shaker conveyor pass to the optical classification equipment where glass is recovered and fibrous material is further shredded in a secondary paper shredder. All secondary operations are also dry and it is visualized that with this amount of handling, all moisture is essentially eliminated.



TELEDYNE SYSTEM

16.3.2.5.

16.3.2.6 University of Texas

PVC and PE Recovery Process

Many reclaimed plastics are often mixtures of Polyvinyl Chlorides and Polyesters which are generally incompatible and useless to processors.

The Department of Chemical Engineering at the University of Texas has done extensive research on the use of Chlorinated Polyethylene as a compatibilizer for PVC - PE and other polymer blends.

Efforts indicate that the material added to mixed plastics at the 10% to 30% level can act as a binder enabling such blends as PVC, PS and PE to be reprocessed conventionally for selected commercial products.

Two entrepreneurial groups are developing other proprietary chemicals claimed to be much more cost effective than Chlorinated PE. These are now being evaluated.

16.3.3 Chemical and Miscellaneous Processes Developing Technology.

These processes which have been worked on largely in the laboratory or pilot plant are directed towards conversion of solid waste to protein, alcohol, yeast, glucose, fat and cattle food products. Economic values have not been established. Included are:

Louisiana State University
St. Edwards University
Gillette Institute
Dartmouth College

See Drawing No. 982-130-8.

TABLE 16.3.3

SUMMARY OF RESOURCE RECOVERY PROCESSES

Chemical and Miscellaneous Processes - Developing Technology

Name and Location	Principal Product	Other Products	Capacity (Tons/Day)	Capital Cost ($/Ton/Day)	Operating Cost ($/Ton)	Revenue ($/Ton)	Net Cost ($/Ton)	Preliminary Separation Required Wet or Dry	Development Status
1. Louisiana State University	Protein Cattle Feed	Ferrous Metals Non-Ferrous Metals Glass	Demonstration Plant Proposed	N/A				DRY	100 lb. per day pilot plant built in 1969 and operated until 1971.
2. St. Edwards University Austin, Texas	Fats Soil Conditioner	Ferrous Metals Non-Ferrous Metals Glass	Pilot Plant Proposed	N/A				WET	Pilot plant batch. Tests only.
3. Gillette Institute Rockville, Maryland (Photodegradation)	Alcohol Yeast Acids	Ferrous Metals Non-Ferrous Metals Glass		N/A				DRY	Laboratory research started late 1972.
4. Dartmouth College Hanover, New Hampshire	Glucose	Ferrous Metals Non-Ferrous Metals Glass		N/A				DRY	Laboratory research started late 1972.

16.3.3.1 Louisiana State University
Baton Rouge, Louisiana.

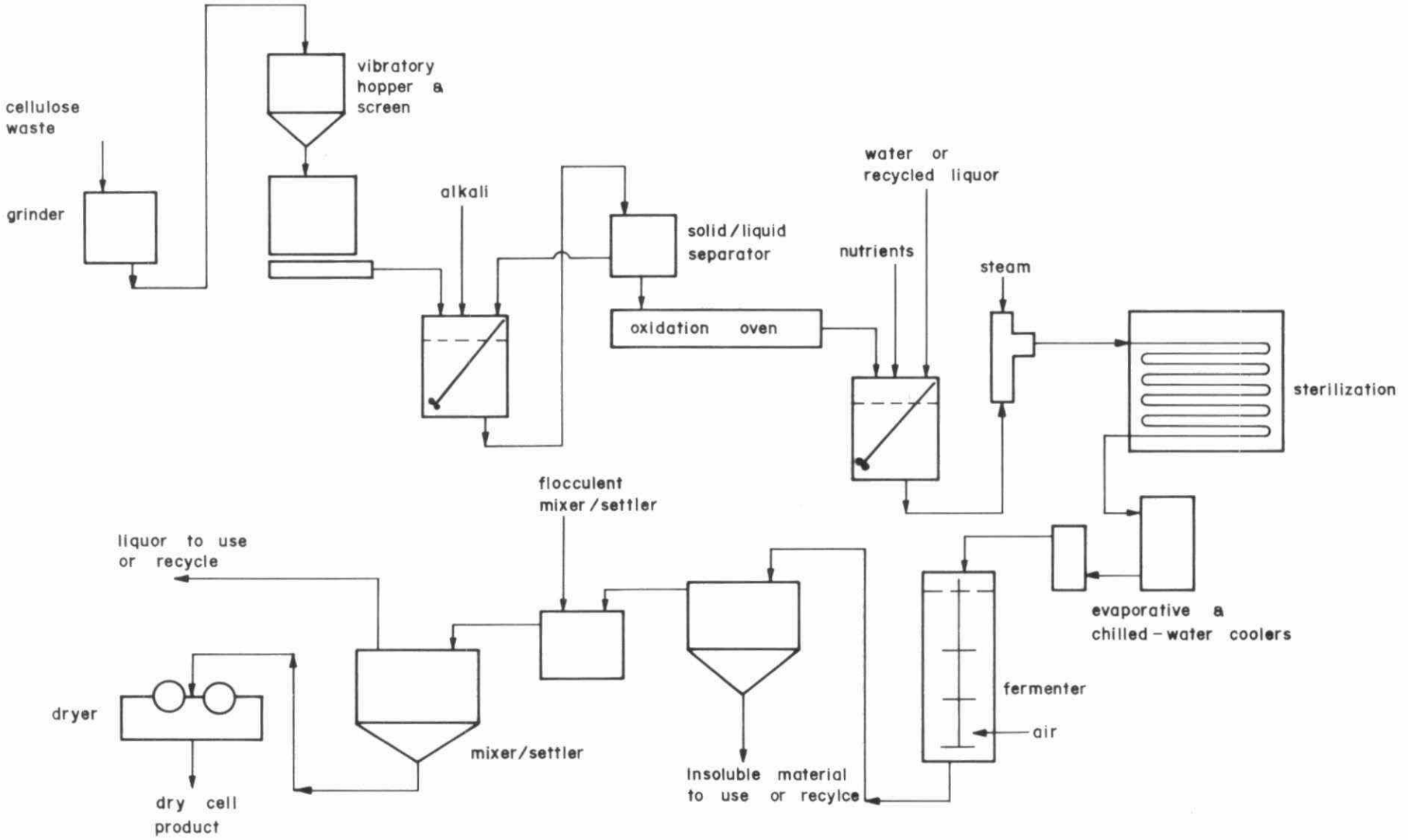
A pilot plant process to demonstrate the biological conversion of cellulose materials to a protein. A market value for the product has not been established.

The cellulose, which was a sugarcane bagasse, was first ground, then transferred to a cyclone where solids were extracted. By means of a vibratory live-bin hopper and a vibratory metering screen feeder, the cellulose was fed to a slurry tank. From the slurry tank it flowed to a solid-liquid separator for dewatering prior to entering an oxidation oven. From the oxidation oven the cellulose dropped into a re-slurry tank where it was mixed with de-ionized water and appropriate nutrient salts. This comprises the treatment part of the process and the slurry was now ready to enter the sterilization section where it was pumped into a steam injection system where the feed stream was brought up to sterilization temperature and pressure. The final step in the sterilization process was the cooling of the feed stream to a temperature compatible with the contents of the fermenter. This was accomplished in two steps by an evaporative cooler and a chilled water cooler.

16.3.3.1 (Cont'd)

The feed stream flowed from the chilled water cooler into a fermenter and then to the harvesting section. The single cell protein produced was a light brown-yellow powder having a crude protein content of from 50% to 60%. The remainder of the product was suitable as cattle feed.

While this work specifically pertains to sugarcane bagasse, it is felt that the cellulose fraction of solid waste could also form raw feed stock for this process.



LOUISIANA STATE UNIVERSITY

CONVERSION OF CELLULOSE

16. 3. 3. 1

16.3.3.2 St. Edwards University
Environics Centre,
Austin, Texas. 78704

A conceptual plan for use with a new town site where ground solid waste and sewage treatment would be combined and processed through an activated sludge Aerobic treatment system, recovering metals, fats and soil conditioners.

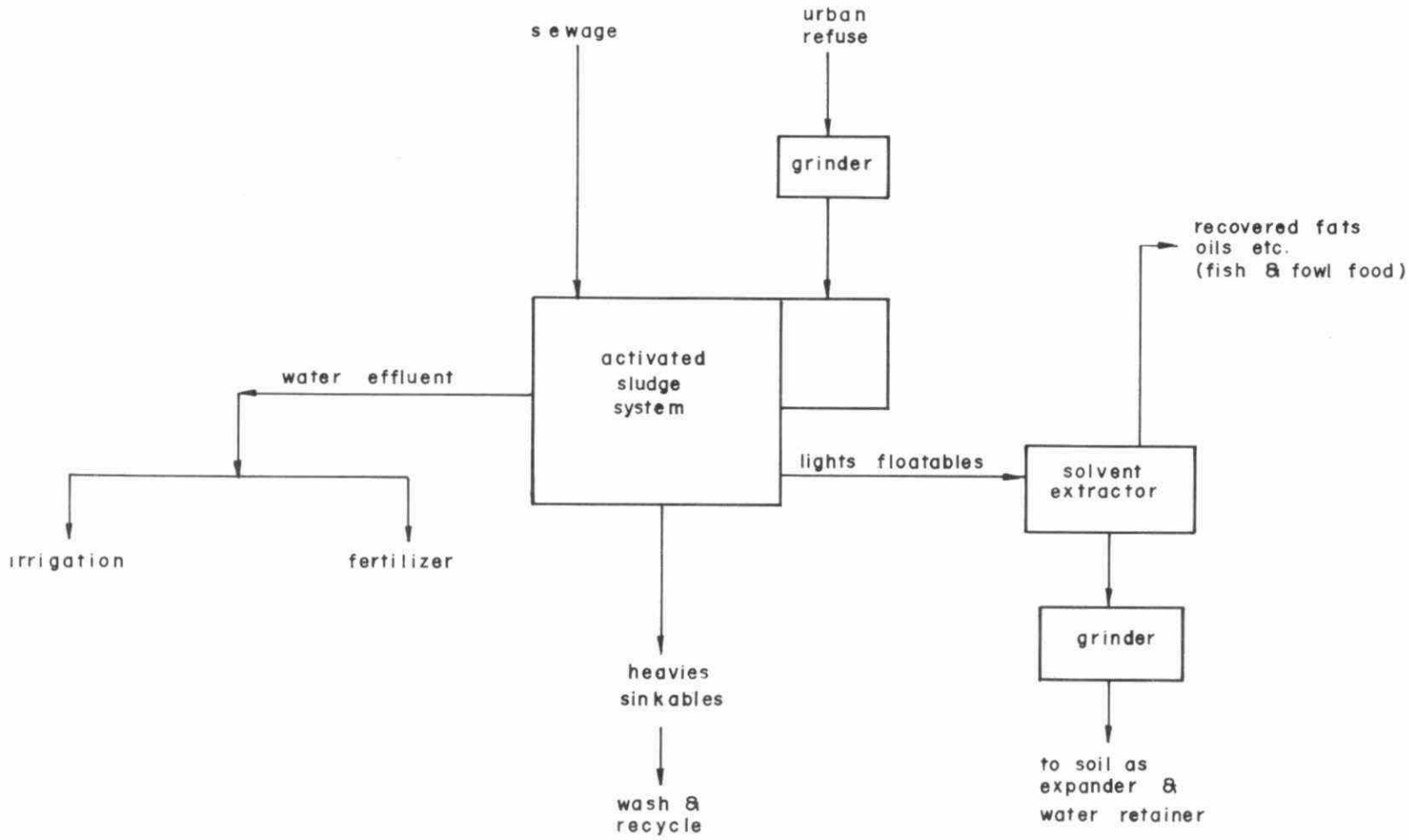
Dispersed throughout and surrounding this "model" city would be areas of agriculture, parks and forests established and maintained with the help of sludge and "fertile waters" from the treatment plant.

There would be three product streams from the activated sludge system.

(a) Heavy material stream which would include metals and other heavy components. These materials would settle out and be recovered and sold as scrap.

(b) Light material stream, including floating light material such as fats, oils, plastic, wood, etc.

(c) Water and sludge stream by far the largest stream would be the source of soil conditioners and soil expanders and provide water for irrigation and recycling. Batch testing only has been conducted.



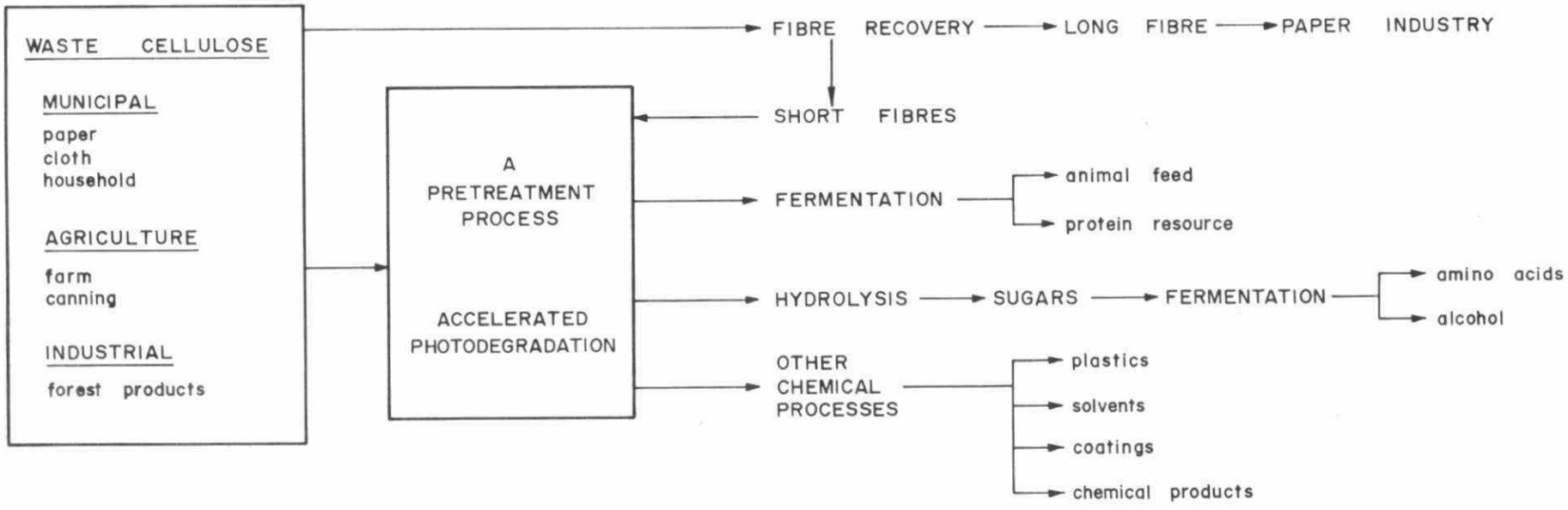
ST. EDWARDS UNIVERSITY - SOLID WASTE FOR AGRICULTURAL USE 16.3.3.2

16.3.3.3 Gillette Research Institute
1413 Research Boulevard,
Rockville, Maryland. 20850

A research concept utilizing accelerated photo-degradation of cellulose molecules, making them more like starch or sugar than cellulose.

The cellulose would be treated with an inorganic salt such as sodium nitrite and then exposed to ultra violet light. Only a few salts are effective in causing the light to efficiently disrupt the cellulose molecule and hence make the waste cellulose more suitable for further processing. Once the waste cellulose has been so treated, it can more readily be transformed into useful chemicals such as alcohol, yeasts, or amino acids.

It is believed that the photolytic treatment might be a key step in further schemes for the manufacture of useful products from cellulose. While laboratory work has been done, a pilot plant has not as yet been established.



GILLETTE RESEARCH INSTITUTE

PHOTODEGRADATION OF CELLULOSE 16.3.3.3

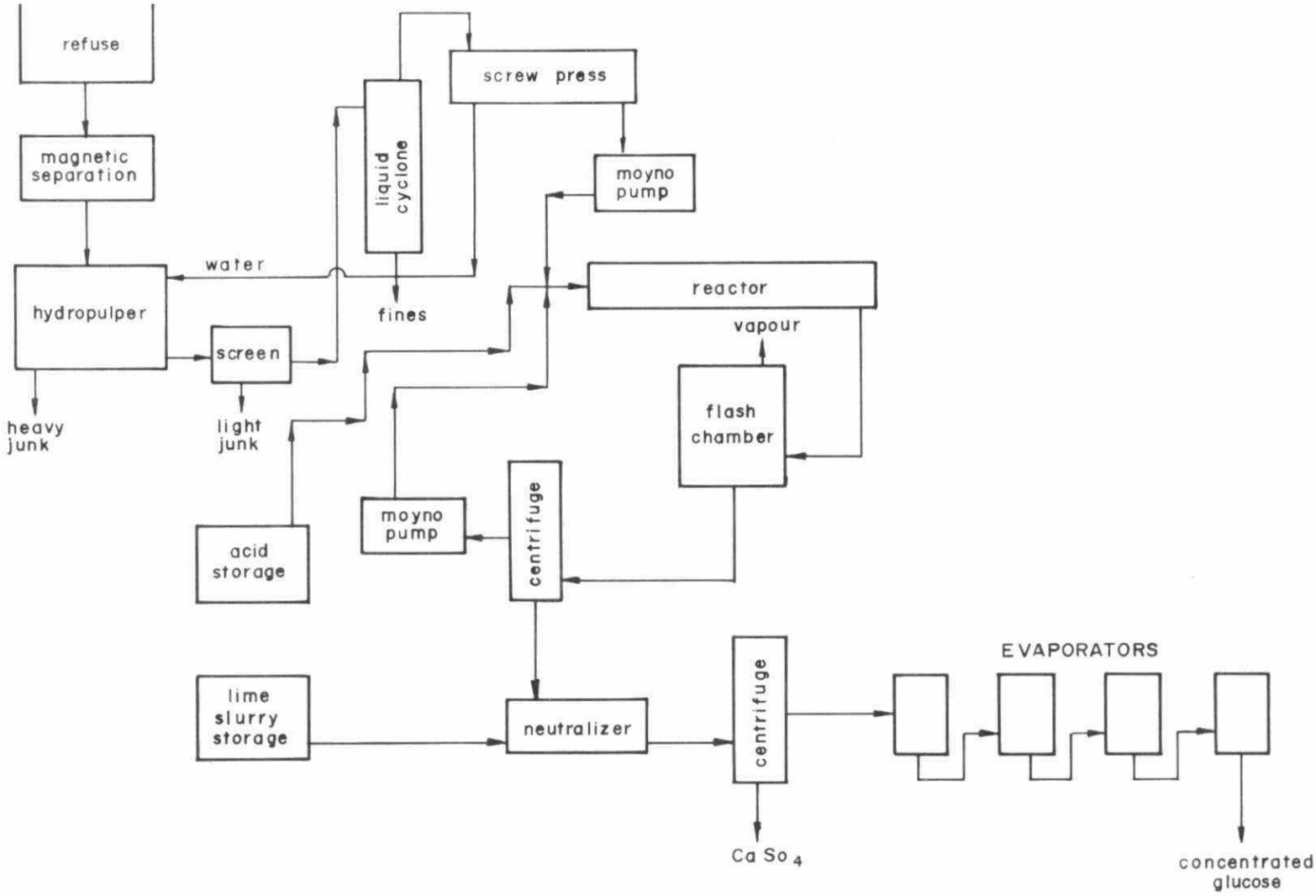
16.3.3.4 Dartmouth College
Thayer School of Engineering,
Hanover, New Hampshire.

A laboratory investigation of the acid hydrolysis of refuse to recover glucose. The concept calls for a three-stage process, including:

1. The separation and pre-treatment of raw refuse.
2. The hydrolysis of cellulose material.
3. The concentration of the sugars.

The first stage would remove, for recovery, the majority of the non-cellulosic material while pulping the cellulosic material which would be hydrolyzed to sugar in the tubular flow reactor by the addition of sulphuric acid and heated water. Following acid neutralization, the final operation of concentrating the liquors is performed in a multiple evaporator system.

The plant would use refuse, process water, sulphuric acid and lime and the output would be ferrous and non-ferrous metals, plastic inerts, hydrolysis waste and concentrated glucose sugar solution.



DARTMOUTH COLLEGE - ACID HYDROLYSIS OF REFUSE

16.3.3.4.

16.4 Secondary Industrial Processes

There are a number of industrial processes already making use of reclaimed components from solid waste. A few of these have been briefly described. They include:

De-tinning Processes
De-inking and Pulping Process
Colour Separation of Glass
Foaming Glass
Fiberizing Glass
Rubber Reclamation Process
Textile Salvage
Baling Processes
Glass Rubble Building Panels and Blocks

16.4.1 De-Tinning

General

Technology for recovery of tin from the cans or tin plate scrap has been in existence since 1905. De-tinning of tin plated steel recovers both the tin and the steel of the body of the can.

A de-tinning operation has two reasons for its existence. Tin is not produced in quantity in North America, and tin is a contaminant in the steel industry, causing a reduction in strength in steel if included in quantities greater than .06%. When the tin is recovered, two products are immediately available, tin and #2 Scrap Steel.

16.4.1 (Cont'd)

Process Description

Three chemical methods have been in use; Electrolytic Alkaline, chlorine de-tinning, and caustic soda and oxidation. Recently thermal separation methods have come into use which do not necessarily recover the tin because the average recoverable tin content in tin cans has decreased from 30 lbs/ton to 9 lbs/ton. The development of lacquer and plastic coatings has also made the chemical processing more difficult. At present, practically all de-tinning plants in North America, (approximately 17 or 18) are located close to a can manufacturer, with the raw material being the scrap generated by the can plant. Present processes can recover all except .02% to .04% of the tin, including that of the base steel which, of course, cannot be removed. The .02% to .04% left is largely contained in residual washing solution and portions of tin plating that the solution could not reach.

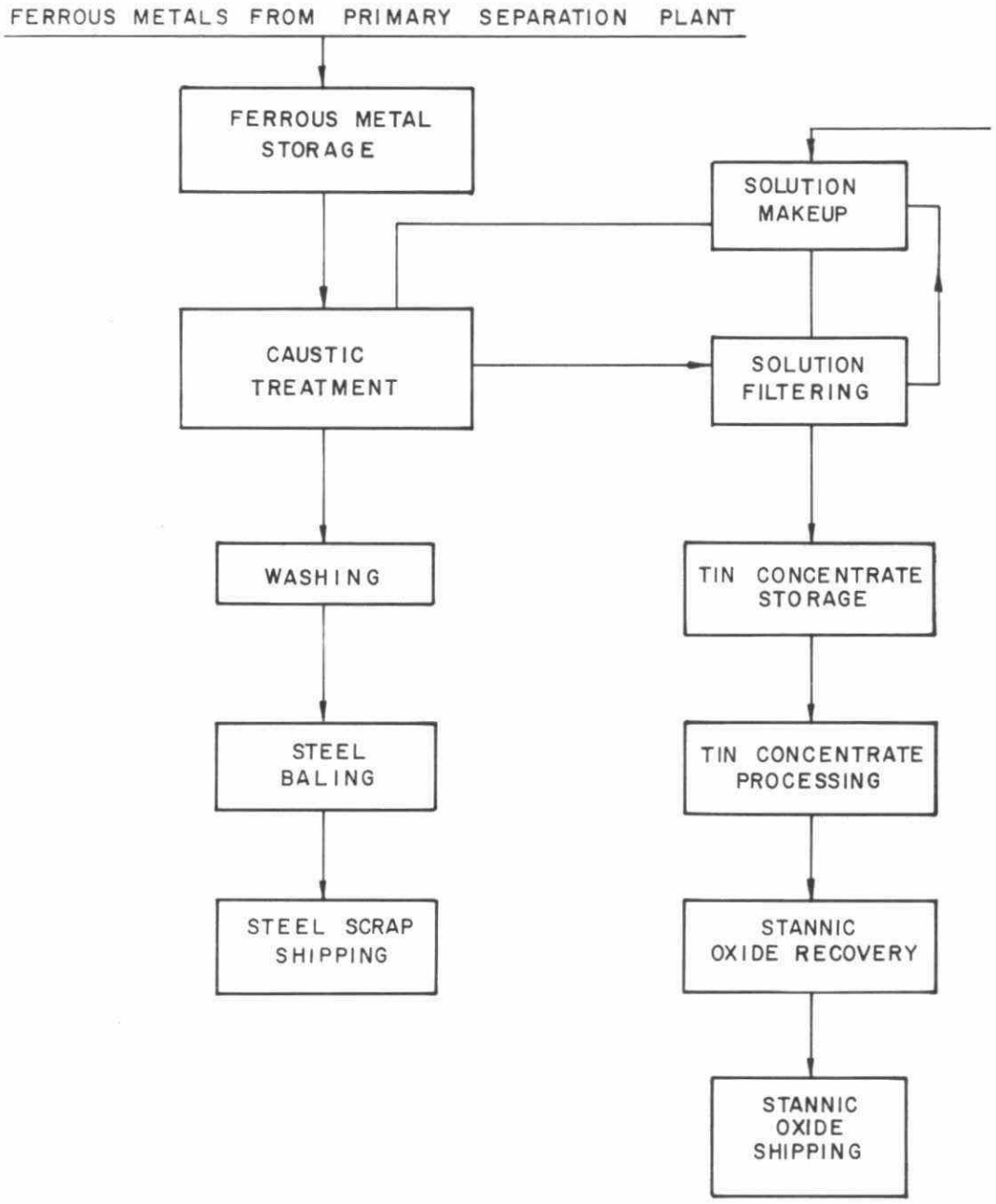
The Canadian canning industry produces over five billion cans annually for the food and beverage inudstry of which 1.3 billion are beverage containers, most of which have aluminum tops.

None of these are presently recovered. For Metropolitan Toronto, this would represent 90,000 tons of steel per year and 450,000 lbs. of tin.

Problems associated with aluminum tops and lead in solder seams have been overcome.

The latest de-tinning processes can recover the steel and tin from ferrous metals in solid waste. The minimum tonnage required to establish a viable operation is between 12,000 and 15,000 tons per year, depending on the location.

In Canada there is presently only one de-tinning plant in operation.



DE - TINNING OPERATION FLOW DIAGRAM 16.4.1

16.4.2 De-Inking Processes

General

In general, the very extensive research facilities in the pulp and paper field have directed the greatest portion of its effort to the production of paper from new material. It is to be expected that both the price of paper and the dwindling areas suitable for the growing of pulpwood will tend to channel greater technological effort into waste fibre reclamation.

De-inking processes and the technology developed by the industry can provide a sound basis for the eventual reclamation of considerable value from the cellulose fraction of solid waste.

De-inking processes not only involve the removal of ink, but are complete processes that separate the cellulose fibres from all other foreign materials such as clay, starch, titanium dioxide, calcium carbonate, dyes and pigments, rosin size, surface sizing, functional coatings (glue, etc.), laminating materials, waxes, and other non-cellulosic substances. What has been classified as "De-inking processes" is in reality "Waste Paper Fibre reclamation processes".

An examination of the technology of de-inking indicates that most processes developed require

16.4.2 (Cont'd)

control of the raw material fed into the process, particularly with regard to fibre originally used in making the paper. These processes are directed to newsprint containing 80% groundwood, blends of wastepaper containing up to 50% groundwood, 20% - 50% groundwood and 10% - 20% groundwood. The processes may be either batch or continuous, each having characteristics and advantages and disadvantages.

16.4.2.1 A typical de-inking process for low groundwood content would be:

1. Dry paper is added to a cooking vessel such as a hydrapulper containing water with chemicals already present.

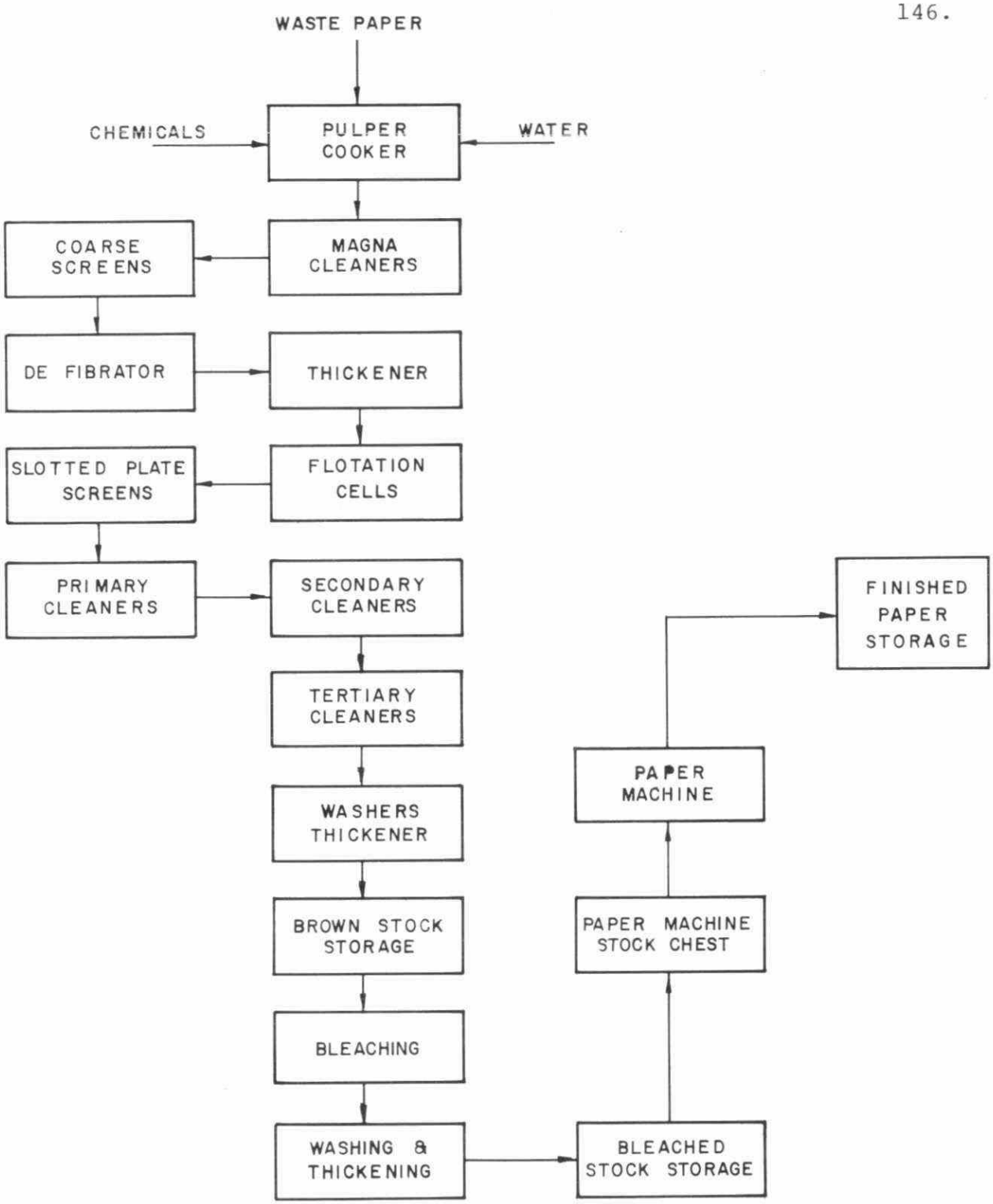
2. More water is added with continuous violent agitation so the final consistency is 5% - 8% at 180^{o} to 210^{o}F - cooking is continued until a sample drawn from the cooker gives a satisfactory test sheet after washing on a screen with fresh water.

3. Cooked stock is dropped to a stock chest, then pumped through suitable equipment to complete the defibering.

4. Diluted stock is passed through rifflers or centrifugal cleaners to remove heavy trash, then is screened, passed through high head centrifugal cleaners to remove heavy dirt, and finally washed and bleached. If a considerable amount of carbon (from printers ink) remains in the fibre, a carbon removal process is required as carbon cannot be bleached.

Other de-inking processes using different chemicals in the initial cooking and different pieces of equipment are used for waste papers of medium and high groundwood content.

Defibering and de-inking are subject to a host of variables, operating conditions and final product requirements.



NEWSPRINT DE-INKING PROCESS

16.4.2.

16.4.3 Colour Separation of Glass

In order that recycled glass may be acceptable for re-use by a glass container manufacturer, it must be separated by colour. If not separated at source, the glass passed into the solid waste stream quickly becomes fragmented making the task of reclamation more difficult. This has lead to the need to develop a rapid means of selectively and separately concentrating colourless (flint) and coloured glass (amber and green).

The sorting of glass by colour, using commercially available electronic sorters, while a recent development, is proving to be a feasible application. The Electronic Colour Sorting Machine as developed by the Sortex Company of Lowell, Michigan, is composed of four basic components; the feed delivery, optical, electronics, and ejection sections.

Feed Delivery Section comprises two vibrating hoppers in conjunction with two rubber conveyor belts travelling at constant speed. The rate of feed is controlled by a vibrating feeder so that the particles to be sorted are delivered with selected spacing between them along the centre lines of the belts. The particles are thrown from the moving belts in a trajectory 90^{o} to the viewing parts located in the optical section.

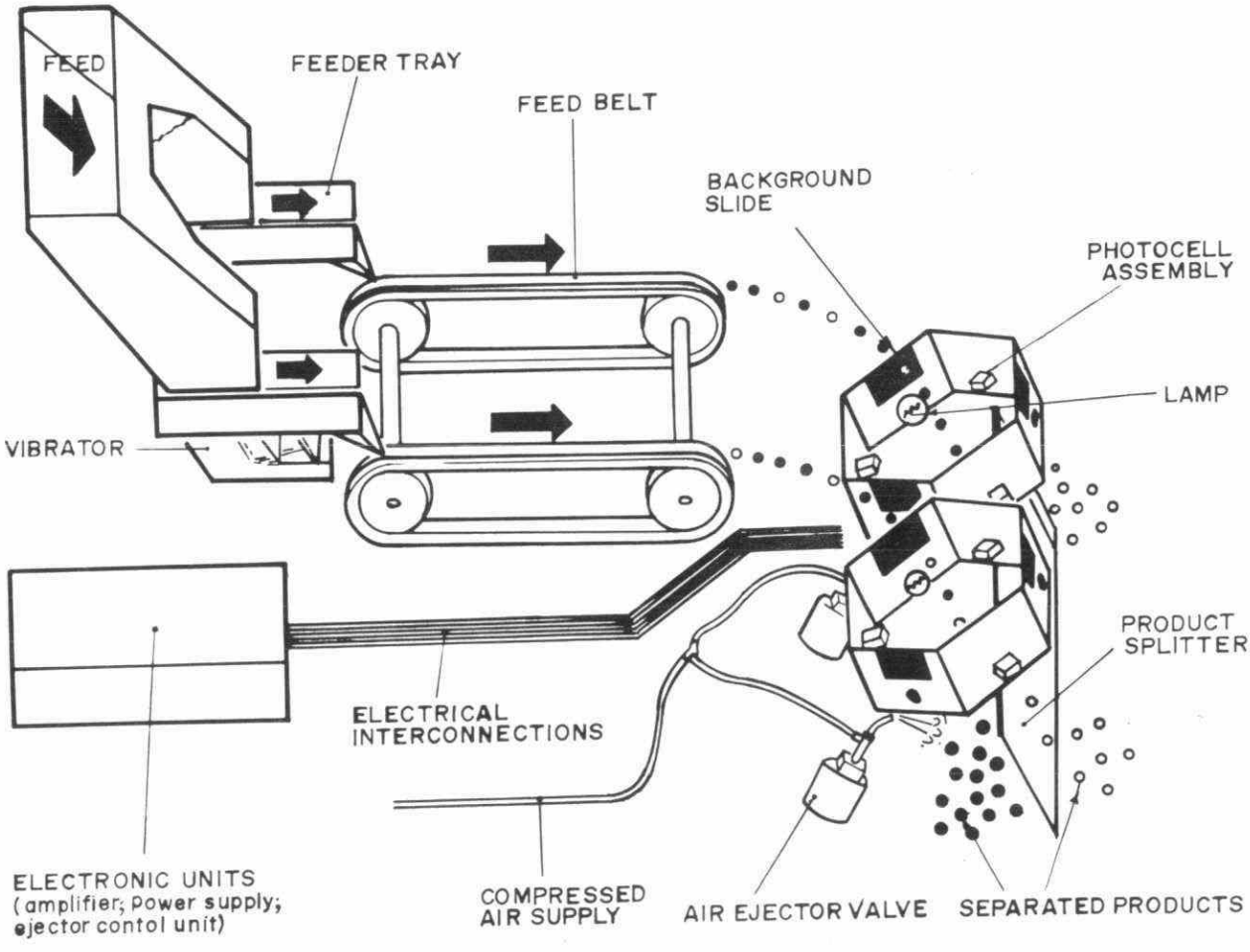
16.4.3 (Cont'd)

Optical Section containing three high intensity lamps as a source of illumination for three photo-electric cells. The cells are spaced 120° apart and the optics are adjusted so that the three cells focus on a common point to give an effective 360° coverage of a particle passing through the point. A suitable filter which enhances the reflective qualities of the particle is positioned over the photocell lens. Directly opposite the cell, a standard background colour plate is positioned to create a null condition from which any deviation is signalled to the electronics section.

Electronics Section. The electronics parameters are manually set for the desired colour separation. In the separation of light particles from darker particles, the photocell signals the electronic system only if the particle viewed is the same as or lighter in colour than the standard background colour plate. The reverse is true when the electronics are set to separate darker particles from lighter particles. In all cases the signal is delayed long enough to allow the particle to fall to a point where it is opposite the ejection section. This takes approximately 30 milliseconds.

Ejection Section is composed of electronically controlled pneumatic valves. When an ejection signal is applied, the valve will open for approximately 5 milliseconds, releasing a blast of high pressure air which blows the desired particle from the stream.

The machine has been successfully used for the separation of glass from incinerator waste as well as samples taken from selected household waste.



COLOR SEPARATION OF GLASS

16.4.4 Foamed Glass

Urban refuse is made up of metallic, organic, and ceramic materials. The metallic and organic fractions, as has been described, may be readily recovered or can be incinerated to recover thermal energy. The ceramics or glass material, made up largely of glass containers, has low value and less potential for re-use, having been made from raw materials which are non-critical and widely available.

The container glass industry has always recycled its own manufactured rejects. They do this by crushing the formed glass into cullet and feeding it back into their process with new batch material. It is not uncommon for these inplant rejects to make up 15% - 25% of all new batches.

The industry has recently indicated its willingness to buy back glass from the consumer, and has stated its ability to handle raw material batches made up of as much as 50% glass cullet. At best then, the industry could only be expected to consume 25% - 35% of the domestic glass which ends up in the waste stream.

The glass industry is most cautious about re-use of imported glass containers and glass from other processes, i.e. window glass, bulbs, picture tubes, etc. It appears from these limitations that in

16.4.4 (Cont'd)

excess of 75% of the glass presently found in urban refuse could not find its re-use by a primary glass producer.

Consequently, these waste glass materials would best be utilized in the manufacture of new commodities where the need for expensive colour sorting, sizing and cleaning, is at a minimum.

One such approach to the new product concept is the conversion of glass waste to a foam material with properties similar to "Foamglas", a commercially available product produced by Corning Glass and marketed as a specialty insulation.

Laboratory work has been performed at the University of Utah and the feasibility of foaming flint (clear) and brown (beer) glass has been established.

The concept of foaming glass is borrowed from nature. Perlite, a naturally occurring volcanic glass, contains large quantities of chemically combined water. Upon heating, the perlite softens and releases the water as steam. The expanding steam foams the glassy perlite, forming a light weight porous material. By reacting water with waste glass, an artificial perlite can be created. After being foamed the cellular glass resembles its natural counterpart with corresponding

light weight and insulating properties.

The experimental process is described as follows. "Glass was first crushed by ball milling then mixed with Calcium Carbonate and water, the resulting blocks were heated slowly in an electric furnace until expansion took place at about 750°C when the Calcium Carbonate decomposed to Carbon Dioxide and Calcium Oxide. The Calcium Oxide dissolved in the glass and the liberated Carbon Dioxide acted as the foaming agent. In order to keep the CO_2 gas from escaping, the resulting block was sintered to seal all passage ways".

It was stated from these laboratory tests that glass foam could be produced from waste glass. The process was simple and inexpensive. The product was a competitive high quality insulating material. The process could help reduce glass solid waste and produce a valuable product. The process used glass as collected without cleaning and sorting and the process could be used in any locality as it did not depend on a glass plant or special glass source.

16.4.5 Fiberized Glass

16.4.5.1 Bureau of Mines
U.S. Department of the Interior,
Tuscaloosa, Alabana.

Research work performed at Tuscaloosa established the feasibility of making mineral wool using varying

16.4.5.1 (Cont'd)

proportions of salvaged glass combined with other materials.

Mixes of molten glass have been fiberized into mineral wool during laboratory studies by impingement of a jet of compressed air on a stream of molten glass.

Mineral wool is used principally for thermal insulation and the absorption and isolation of sound. Both its thermal and acoustic value stem from its structure being a mixture of fibre and air. For this reason, differences in chemical composition within fairly wide limits are relatively unimportant.

"Mineral wool is an ideal use for clean or poorly cleaned waste glass, because even the presence of metal in the batch mixture does not interfere with the wool fiberizing method". Many of the tests conducted have made use of incinerator residue waste.

The process is described as follows:

"The raw material batch made up of residue glass (46% - 78%) dolomite (20% - 52%), and Alumina (2%), was mixed and melted in a gas furnace at 2600^{o}F. The molten glass flowed from the furnace where it was fiberized by an impingement of a jet of compressed air (100 psig) at a right angle to the vertically flowing glass stream. The compressed air has a shearing and fiberizing action

upon the molten glass, breaking it into individual drops and fibres while they are blown into a collection area. As the drops of molten glass are propelled through the air, friction causes them to develop long "tails".

These tails are the insulating fibres".

16.4.5.2 Sealtite Insulation Manufacturing Corp. Waukesha, Wisconsin.

This company has been producing glass fibre insulation utilizing waste glass containers as a major raw material since 1970 at Merton, Wisconsin. The use of waste container glass provides a simplified process as compared with the standard procedure for manufacturing glass wool. The process consists of melting waste glass of any type or colour along with three proprietary additives in a coke fired cupola furnace at about 2500^{o}F. The charge to the melting furnace consists of 25% to 50% waste glass and 50% to 75% of the combined additives.

The molten glass is then transferred from the melting furnace to a spinneret which resembles a cotton candy machine. Glass fibres are spun off from the spinneret and carried along in a fibre forming chamber by jets of steam. The interaction of the steam jets and the molten glass forms the fibrous material.

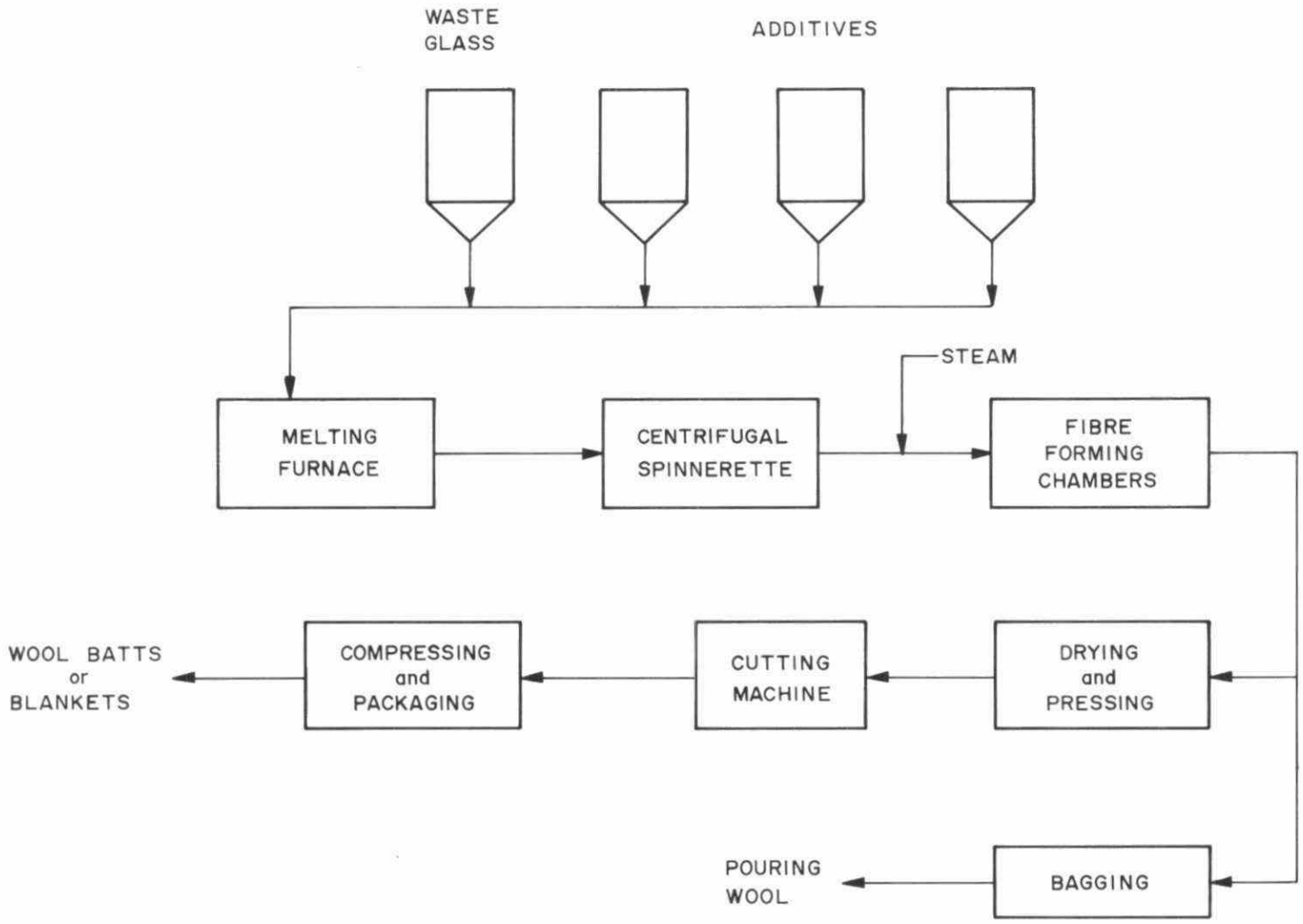
16.4.5.2 (Cont'd)

The fibres have a diameter of 7 to 10 microns and are soft and easy to handle.

The fibrous material is conveyed by a wire mesh conveyor from the forming chamber to a drying and pressing machine. Batts are cut automatically to the required size and compressed and packaged in paper containers.

The Sealtite process for making mineral wool from waste glass is flexible in regard to proportioning of raw materials. For example, mineral wool insulation products which contain from 10% to 50% waste glass can be prepared in this process. Because of this desirable operating feature the process can be adapted to match variations in the available supply of raw material or to take advantage of change in raw material costs.

Mineral wool made from recovered glass is directly comparable with and substitutable for mineral wool made by conventional means.



SEALTITE MINERAL WOOL FABRICATION 16. 4. 5. 2

16.4.6 Rubber Reclamation

Unlike the recovery of many other solid waste materials, the recovery of rubber is already established as a practical method which is not severely constrained by scrap quality such as the mixture of natural and synthetic rubbers.

The availability of reclaimed rubber for use in the rubber goods industry has been instrumental in minimizing rising costs of crude rubber.

Reclaimed rubber, it is claimed, has technological advantages over synthetic and crude rubber. It is better able to absorb fillers and may be mechanically masticated more rapidly than synthetic or crude rubber.

In addition to recycling of reclaimed rubber, some experimental work has been done with the pyrolysis of scrap automobile tires to produce carbon.

The rubber content of mixed municipal solid waste consists of hot water bottles, shoes, rainwear, heels, floor mats, and household items containing rubber pads, gaskets, washers and occasionally rubber tires.

Rubber tires are most frequently disposed of at service stations and constitute the major source of scrap rubber presently being recycled.

16.4.6.1 Process Description

Two types of re-processing are presently being practised. Using mostly tires as a source of raw material, National Rubber removes the steel bead, re-shreds the remainder, removes the fibre cord by air classifying, and is able to use the balance in products normally marketed.

This operation was marginally competitive with raw rubber obtainable at 20¢ per pound, but present costs of 60¢ - 65¢ per pound make reclamation a much more viable situation.

Goodyear have also developed their own shredding and de-vulcanizing operation and use as much reclaimed rubber in tire products as safety restrictions and tire specifications allow.

16.4.7 Textile Salvage

Rags are generally salvaged by industrial brokers from used clothing depots, and find a use in the manufacture of fine writing paper or heavy roofing felt papers and also as wiping rags.

In general, the removal or separation of rags from mixed solid waste is not practical because of the difficulty in separating natural and synthetic fibres and because of the presence of contaminants. Handsorting is the only means of obtaining a satisfactory product suitable for cleaning and re-use. While expensive, the salvage of rags has been reported from two compost plants when the market price for rags exceeds $40.00 per ton.

16.4.7.1 Textile and Carpet Fibre Re-processing (Plastic Fibres)

16.4.7.1.1 General

Before the current resin shortage, stretched plastic fibres such as those used in textiles and carpets, had been considered too difficult to handle because of their abrasive effect on size reduction equipment. Gel content is also often too high to permit filament orientation after re-extrusion.

Several recently developed size reduction systems are now available for recovering fibre scrap. A brief description of some of the processes follows.

6.4.7.1.2 Taylor-Stiles System

Taylor-Stiles Division of Envirotech Corp. of Cleveland, produces an automatic size reduction unit that accepts 500 to 1000-pound bales of fibre scrap that are cut successively by a guillotine, a heavy duty rotary cutter, and a grinder and conveyed to a pelletizing extruder. Pellets are used by an injection molder.

Five existing installations operate at 1500 pounds per hour with fifteen more becoming operational this year. Each system is priced at $200,000 to $400,000.

6.4.7.1.3 Sprout-Waldron-System

Sprout-Waldron of Muncy, Pennsylvania, has recently installed a 1000 pound per hour system that guillotines the bales, reduced by a rotary cutter, and two stage precision mill. The powdered nylon product is fed directly into an injection molder. The system is valued at $300,000, and is due for start-up in April, 1974.

16.4.8 Baling

Recognizing the possible need for baling of either extracted products or the discard waste from a Resource Recovery Plant, baling is being considered as a secondary process which may be included in an Experimental Reclamation Centre.

While considerable work has been done on the baling of paper and metals, there is still a need to determine the behaviour of single solid waste components and different solid waste mixtures under varying compaction conditions. The control of springback and compaction of Wet Solid Waste materials offer the opportunity for further research.

Baling is the process of reducing the volume of a material by pressure and at the same time increasing its density.

Baling may be applied to any of the components being extracted from a Resource Recovery Centre or it may be applied to municipal refuse designed for landfill.

In either case it offers potential benefits, including sanitation, ease of handling, economy in shipment, extension of landfill life, and improved stability of the fill site.

Balers are manufactured in many sizes and are being used primarily to bale paper, corrugated, rags, scrap metal, whole automobiles, and municipal waste.

16.4.8.1 Paper Baling

One method of paper baling consists of loading the waste paper or corrugated onto a feed conveyor which passes the material to a hogger or shredder where it is torn into small pieces. It may then be blown through a separator and fed into a baler feed chute.

As the scrap builds up in the chute, an electric eye may activate the hydraulic ram which moves horizontally compressing the scrap into one or more inches of bale length.

When the bale has been formed to the desired length, it is tied with wires. Bales are uniform in size, usually about 72 inches long. Density of the bales may be controlled, weighing between 300 and 1400 pounds.

16.4.8.2 Metal Baling

In the scrap metal business, triple compression heavy-duty hydraulic presses turning out high density bales are common.

Bales are usually 36 inches x 24 inches x 60 inches, weighing between 4000 and 7000 pounds. Scrap is loaded into a hopper where it is weighed before being dumped into the charging box.

The first compression ram moves in from the end of the box followed by a second ram from above and the third ram from the side. The third ram pushes the finished bale through the vertical gate onto a chute.

16.4.8.3 Municipal Waste Baling

There has been some research in the U.S. using high density balers to bale municipal refuse. Also, the implications of applying high pressure compaction to solid wastes for rail haul and disposal have been studied.

It is claimed that solid waste bales permit an increase in landfill space utilization by about 60 to 90 per cent since they could average from 1600 to 1900 pounds per cubic yard, as compared to a maximum density of about 1000 pounds in most of the existing landfills where loose refuse is buried.

To date, Minneapolis is the only city in the U.S. which is baling municipal refuse for shipment to a landfill site.

Baling appears to have its application in a large community using rail haul and requiring high density landfilling.

16.4.8.4 A Japanese proposal for disposing of municipal waste known as the Tezuka Refuse Compression System has

16.4.8.4 (Cont'd)

received much publicity but has not found an application in Canada or the U.S.

This system utilizes conventional high density baling to which various coatings have been applied. It is suggested that these coated blocks may become available as building blocks, but a great deal more knowledge would be required before this was advocated.

16.4.9 Glass Rubble Building Panels and Blocks

16.4.9.1 Thixon Corporation
1400 Teller Street,
Lakewood, Colorado. 80215

The development of processes for using waste container glass in the manufacture of construction materials is receiving a great deal of attention.

The Colorado School of Mines, Research Institute investigated the fabrication of brick-sized products using scrap glass and inorganic wastes and various ceramic additives combined through vibro-casting and firing techniques. This work led to the conclusion that large waste glass-rubble construction panels would be viable commercially.

Such panels could be used either as structural building units or as decorative facing panels competing with the large brick panels and precast concrete now used in building construction.

A pilot manufacturing plant has been established at Golden, Colorado, to manufacture various sizes and shapes of structural and facing panels made by the glass rubble vibro-compaction method known as "vibro-casting".

These panels called Thixite Panels have been used to construct a large picnic pavillion in Denver, Colorado. The process for producing building, or facing panels (up to 10 feet x 4 feet x 4 inches) is described as follows:

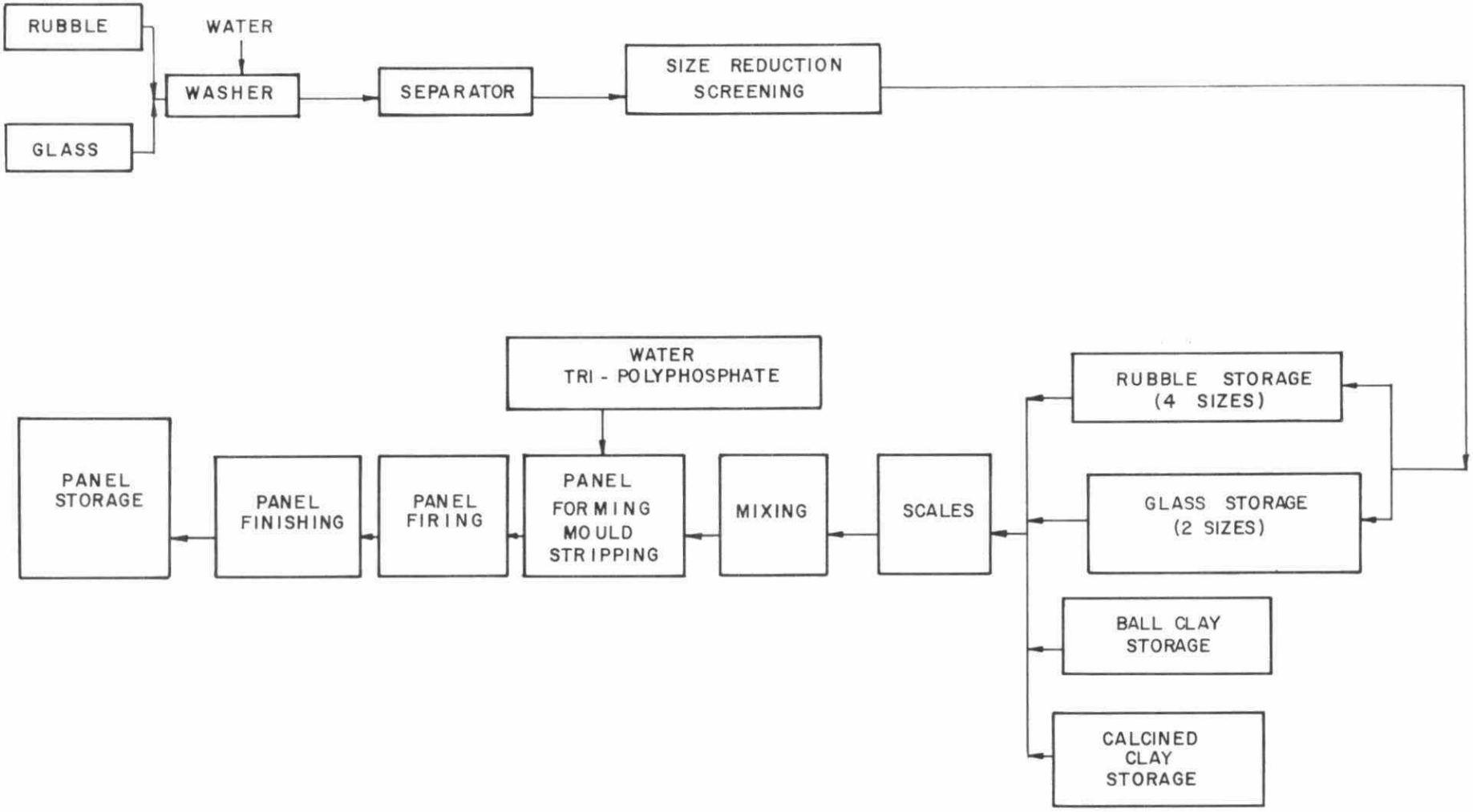
"The principal raw materials, rubble, waste glass and clay, are brought into the plant through a screen and conveyed to storage bins. These materials are separately washed to remove plaster and dirt and then conveyed to primary and secondary crushers. The crushed rubble is separated into four size fractions and the crushed glass stored in two size fractions. Ball clay and calcined clay is used in the process.

Raw materials are conveyed from weigh scales to batch mixers. The batch sufficient for one panel is conveyed to the forming table equipped with a fibrator where it is cast into a mould. The panel remains in the mould until an initial set takes place. The mould is then stripped and the panel

16.4.9.1 (Cont'd)

passed through a drier and a tunnel kiln which are gas fired. The panels remain in the drier for four hours where the glass is softened to provide a binding action for the mix in the panel.

After discharge from the tunnel kiln, the panels pass to the finishing area for sand blasting, etc."



PRODUCTION OF GLASS - RUBBLE PANELS

16.4.9.1.

16.4.9.2 Superior Concrete Products Ltd.
Lambeth, Ontario.

This firm has successfully produced several prototypes of a patented concrete block containing 40 per cent crushed reclaimed glass.

The method uses glass instead of stone chips and the block has the appearance of a terazzo or marble.

An assured supply of a large quantity of glass is being sought by this company.

16.4.10 Plastics Recovery Processes

General

Since the era of cheap oil is gone, probably forever, the old concept that cheap plastics is next to worthless has also disappeared. Suddenly scrap plastic has become worth anywhere from 10¢ to 30¢ per pound. With the developing shortages, more processors are buying grinders and closing the reclamation loop around extrusion, injection and blow molding operations.

The many plastics in common use, each with different properties and characteristics and in many cases, bonded to other materials, have presented formidable obstacles to reclamation.

Intensive research programs should, however, see the commercialization of various new techniques for reclaiming plastic.

16.4.10 (Cont'd)

At present, there are a number of known commercial processes for recovering plastics, all being newly developed and proprietary with minimal information made public. Two such processes are referred to here.

16.4.10.1 Process Description

PVC Recovery Process

Developed by Hafner Industries of New Haven, Connecticut, for the recovery of PVC from coated wire, and coated fabrics, the process can recover PVC from most plastic and non-plastic products and ultimately from municipal waste.

Semi-commercial tests to date have produced resin, in pellet or power form, that exhibits properties equal to or better than virgin material, particularly in regard to thermal stability.

Production runs with 100% reclaimed material on standard machines have been satisfactory.

A five million dollar, 35,000 ton per year plant, partially funded by the Connecticut Development Authority, is expected to be in operation in 1975.

16.4.10.2 Polyster Recovery Process

A process developed by Gerwain Chemical Corp. of Frackville, Pennsylvania, has a solvent extraction

plant on stream recovering 3000 tons per year of PVC and is also recovering thermoplastic polyester from x-ray and photographic film and could reclaim it from tire cord and textile fabric.

The process converts the polymers to injection molding compounds that compete favourably with nylon, PC and acetate.

The properties are attained by chemicals causing polyester stabilization which diminishes heat sensitivity.

The material produced is suitable for high performance structural uses. A plant presently in operation will produce 1500 tons this year and will be expanded as demand increases.

A P P E N D I X 1

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A P P E N D I X I I

GLOSSARY OF TERMS AND ABBREVIATIONS

Aerobic Digestion - the breakdown of organic components by microbial action in the presence of oxygen, composting.

Air Classification - a method of separating materials in an air column by differences in aerodynamic quality and density.

B.O.D. - biochemical oxygen demand.

Bone Dry - as dried in an oven at $105^{o}C$ for 24 hours.

B.T.U. - British Thermal Unit.

Chemical Conversion - processes which chemically convert the waste into other organic products.

C.O.D. - Chemical Oxygen demand.

Compost Processes - Aerobic digestion.

Combustible Waste - includes paper, cardboard, cartons, wood, boxes, excelsior, plastics, rags, bedding, leather, rubber, leaves, yard trimmings, household waste, all of which may be oxidized.

Dry Process - processes which allow the handling of solid waste directly as received without the addition of water.

Energy Recovery Processes	- processes that recover the energy content of mixed municipal wastes either directly by burning, or indirectly by first being converted to another form such as gas or oil.
Elutriation	- a method of density separation in a liquid medium (usually water).
Fibre Fuel Recovery	- an energy recovery process where the combustible fraction of solid waste is extracted, shredded and used as a fuel, replacing conventional fuels.
Glass Cullet	- crushed waste glass.
Industrial Solid Waste	- includes discarded materials and equipment, mine tailings, packaging, sludges removed by treatment of liquid waste.
Incineration	- means reduction of solid waste by controlled burning, not necessarily accompanied by materials recovery from the residue or energy recovery in the form of steam or electricity.
Materials Recovery Process	- processes which separate and recover the basic materials from mixed municipal wastes.

Modular Concept	- means the ability to add to or close down separate functions of the process without interruption to the whole operation.
Non-Combustible Waste	- includes metals, tin cans, foils, dirt, gravel, bricks, ceramics, glass, crockery, ashes.
PE, PP, PS, PVC, PC	- polyethylenes, polypropylenes, polystyrenes, polyvinyl chlorides, polycarbonates.
Pyrolysis Process	- refer to processes which thermally decompose the mixed municipal waste or a fraction of it in a controlled oxygen deficient atmosphere.
Recycling	- generally referred to as the re-use of an object in its original form.
Sanitary Landfill	- is an engineered disposal site in which solid wastes are buried in a manner to avoid environmental pollution. It consists of spreading solid waste in thin layers, compacting them to the smallest practical volume and covering them with earth each day.

Secondary Process - where separated components from solid waste may be further processed to allow re-use in their original form or be re-used in an entirely different form.

Shredded Refuse - solid waste which has been reduced in size through a hammermill or shredder.

T/D, T/wk, T/yr - tons per day, week, year.

Transfer Stations - means a site used for the purpose of transferring solid waste from a city collection vehicle to another carrier more suited for long distance transportation.

Wet Process - processes in which water is immediately added to the solid waste in sufficient quantity to allow the paper fraction to be handled as wet pulp.

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